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China Space Talent

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S C I E N C E & T E C H N O L O G Y P O L I C Y I N S T I T U T E

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Executive Summary

China's space capabilities have increased rapidly over the past two decades such that it now has one of the most active space programs in the world. With the second highest space expenditures of all spacefaring nations, China maintains robust programs in remote sensing; position, navigation, and timing; communications; human exploration; lunar capabilities; and more. These advancements in space have relied on Chinese scientists and engineers to conduct research and develop the technology needed to be an independent spacefaring nation with a successful space program—rather than relying on partner nations.

Few studies have examined the development and utilization of China's space talent. The IDA Science and Technology Policy Institute (STPI) sought to fill this gap. Specifically, STPI set out to answer the following questions:

1. What research institutions in China support the space sector? What specific areas, specialties, or degrees do they focus on? What partnerships, domestic or foreign, do these institutions have?
2. In China, what space sector academic programs and research institutes have high publishing rates and citation indices?
3. What enables Chinese research institutions to attract and retain talent? To what extent is collaboration with other regions of the world an important factor in attracting and retaining talent?
4. What pipelines exist for talent to enter the Chinese space ecosystem? Where do trained students go after completing their degrees?

The study relied on several open sources in Chinese and English, including (a) a literature review on the Chinese education system and how it has evolved over time, (b) an examination of the top space research institutions using space publications and citation analyses, (c) a web scrape of academic institution websites for information on professors, (d) graduate employment reports from academic institutions and employment announcements, and (e) profiles from the China Aerospace Science & Technology Corporation (CASC) and China Aerospace Science and Industry Corporation (CASIC). The study had some limitations; chief among them was the inability to have discussions with Chinese researchers. We attempted to field a Chinese language survey to academics at Chinese institutions, but found a reluctance to discuss the topic and respond to the survey. Furthermore, in our examination of Chinese academic institutions, we limited the scope to the top 20 institutions and did not have the time or resources to expand to a broader set of institutions. Finally, data and statistics on space-specific talent in China are limited, and as such, we based our analysis largely on the analyses of academic institutions identified as having trained the top space talent.

Not all the research questions were able to be answered. In particular, we were unable to identify specific technical areas, specialties, or degrees on which Chinese space talent focus; we instead relied generally on data about aerospace departments. We also had difficulty obtaining data on partnerships between Chinese and international academic institutions regarding the exchange of space talent.

A number of key findings about Chinese space talent emerged from this study:

Finding 1: Academic institutions training the top space talent are similar to the top Chinese research institutions.

Our analysis found that 19 of the top 20 Chinese aerospace research institutions as measured by publication productivity are the same research institutions as those measured by citation rates. Furthermore, the top Chinese aerospace research institutions based on productivity are generally the same as the overall top Chinese research institutions across all fields. Researchers from the Chinese Academy of Sciences (CAS) accounted for 23 percent of all space publications, followed by those from the University of the Chinese Academy of Sciences at 7 percent, Wuhan University at 5 percent, and Peking University and Tsinghua University at 4 percent each.

Finding 2: The majority of faculty at the top Chinese aerospace research institutions are domestically trained.

Upon analyzing faculty profiles of 15 top Chinese research institutions that published employment reports, we found that 83 percent of Chinese aerospace faculty researchers at 15 institutions are domestically trained. Of the remaining 17 percent who received a foreign PhD and returned to China, the United States was the top country where they earned graduate degrees. We also found that those earning a domestic PhD at aerospace institutions tended to remain at the same institution where they received their PhD, indicating a somewhat limited domestic talent migration. This finding is consistent with migration patterns in general science, technology, engineering, and math (STEM) fields and suggests that there is nothing out of the ordinary regarding how aerospace talent is attracted to or retained by Chinese academic institutions.

Finding 3: Most master's and PhD degree holders from top Chinese aerospace research institutions seek employment after graduation.

While not unique to the space sector, our analysis of employment reports from 15 top research institutions found that 25 percent of bachelor's degree holders seek employment, while the remainder tended towards furthering their studies at domestic research institutions. On the other hand, master's and PhD degree holders predominately entered the workforce.

Job fairs were the primary way that students matched with employers. Nearly all top universities reported that CAS, CASC, and CASIC attended at least one university job fair.

Finding 4: Chinese space publications with at least one foreign collaborator were more likely to be impactful than Chinese institution-only publications based on citation rates.

Two-thirds of Chinese publications have no foreign collaborators (n=81,451), but collaboration (based on total space publications) has increased over time. In fact, those publications with at least one foreign collaborator receive a statistically significant higher number of citations per year. That is, publications with foreign collaborators receive 3.9 (± 0.08) citations per year as compared to domestic only publications, which receive 1.6 (± 0.02) citations per year. The United States remains the top country coauthoring space publications with China.

Finding 5: Major space subsidiaries within CASC and CASIC seek trainees with degrees outside of aerospace engineering.

The space sector relies on STEM talent from a variety of different fields that go beyond aerospace engineering. In examining company profiles and job announcements of CASC and CASIC subsidiaries, we found the most frequently listed required major was computer science, mentioned in 31 of the 55 (56 percent) job announcements. This was followed by software engineering, mechanical engineering, electrical engineering, and control science and engineering. Aerospace science and technology was the seventh most frequently listed required major. Overall, there were over 300 majors and disciplines listed among the 55 job announcements that featured required majors, ranging from weapons systems to Marxist theory to accounting and finance.

Finding 6: Attracting space talent depends on benefits offered, particularly household registration benefits.

The dynamics of the labor market for space talent in China are not unique to the space sector. Through analysis of CASC and CASIC employment reports, we found that benefits packages were a key factor in attracting talent. Though the standard compensation and medical benefits package was a factor, a key attraction was bonus points for household registration.

Providing a means of moving an individual's household registration (i.e., 户口 or *hukou*) is a major incentive when attracting top talent because it means that the company will sponsor the employee to work and receive public services in a new locality. The importance of company sponsorship is dictated by the China's *hukou* system, which is a government system for registering households by their addresses so as to regulate migration within the country. An individual's *hukou* indicates whether the individual is from a rural or urban locale, and determines where an individual can work, reside, go to the hospital, and where their children can attend school.

Contents

1. Introduction

A. Background

China's space capabilities have increased rapidly over the past two decades through advances in its space launch vehicles; its achievement of human spaceflight; and its deployment of numerous weather, communications, and position, navigation, and timing (PNT) satellites (Roger et al. 2011). With several hundred thousand employees across several state-owned enterprises (SOEs), and tens of thousands of employees at commercial space companies (Szeftel 2022), only the United States has a more comprehensive space sector.

The seeds of China's space sector were planted in the 1970s; many of its current leaders have been around for 50 years. However, the most rapid growth in China's space sector, by far, has come over the past two decades. During this time, the country's space program and its so-called "national team"— most notably the China Aerospace Science & Technology Corporation (CASC)—have grown in tandem with a long roster of ambitious missions, which have frequently been completed more or less on schedule.

In addition to the several SOEs that represent the vast majority of China's space sector, commercial space companies have been developing since 2014, when the State Council issued the *Guiding Opinions of the State Council on Innovating the Investment and Financing Mechanisms in Key Areas and Encouraging Social Investment*, widely known as Document 60 (State Council 2014). Document 60 called for private investment in sectors such as launch and satellite manufacturing, and allowed for an implicit degree of commercialization.

B. Study

This study examines the development of the talent in China who are fueling and supporting China's space sector. The Science and Technology Policy Institute (STPI) was asked to assess the technical capability in space that China may be expected to attain in the next 10 to 20 years, identify the strengths and weaknesses of China's academic and research programs, and study the extent to which China has been building or losing its space talent today and whether it is likely to do so in the future.

Specifically, the STPI study team set out to answer the following research questions:

1. What research institutions in China support the space sector? What specific areas, specialties, or degrees do they focus on? What partnerships, domestic or foreign, do these institutions have?
2. In China, what space sector academic programs and research institutes have high publishing rates and citation indices?
3. What enables Chinese research institutions to attract and retain talent? To what extent is collaboration with other regions of the world an important factor in attracting and retaining talent?
4. What pipelines exist for talent to enter the Chinese space ecosystem? Where do trained students go after completing their degrees?

C. Methodology

To answer these research questions, we used a mixed method approach. First, we conducted an in-depth literature review in both Chinese and English on how the Chinese educational system has changed over time. We examined how China's science, technology, engineering, and math (STEM) workforce has evolved. This literature review encompassed research papers on the Chinese workforce and news articles describing changes in the space workforce. We also reviewed the educational qualifications of Chinese aerospace academics at select institutions of higher education.

To identify key Chinese aerospace research institutions and the domestic and foreign partnerships they have, STPI conducted a bibliometric analysis of space-related journal articles published between 2005 and 2021 from Web of Science. We identified 112 journals and 51 conference proceedings that focused on space research and applications. We limited our bibliometric analyses to journal articles published in these journals and proceedings. The detailed methodology of how the publication database was used can be found in Appendix A. We also identified those research institutions that were the most productive as measured by high publication rates and those that published articles having the highest impact as measured by high citation rates. Finally, we assessed which domestic research institutions collaborated with other domestic research institutes, and with which foreign countries, and the names of the institutes with which they collaborated.

To better understand the existing talent engaged in space research in China, we web scraped faculty profiles from aerospace-related departments from the top 10 institutions. To determine where trained students go after completing their degrees, we analyzed the most recent graduate employment reports for 15 of the top 20 research institutions for which data were available. Lastly, we reviewed recent job announcements from CASC and the China Aerospace Science & Industry Corporation (CASIC) to better understand what skill sets China space SOEs are looking for and the incentives and benefits they provide to attract talent with these skills. More details about our methodology can be found in Appendices A and B.

D. Caveats and Limitations

One of the most significant limitations to this study was the lack of access to Chinese scientists and engineers who were trained in China. We did attempt to field a survey and engage in discussions with academics and space industry employees, but we had a very low response rate as many people were reluctant to discuss this topic.

Another limitation involved the analysis of the graduate employment reports. First, the data were limited to only some of the institutions of higher education. Second, the data reported were not consistent across institutions. Finally, the top aerospace institutions are likely producing China's top talent, but given the size and breadth of the higher education landscape, the majority of the space workforce is likely coming from institutions outside of the top ones.

E. Organization of Report

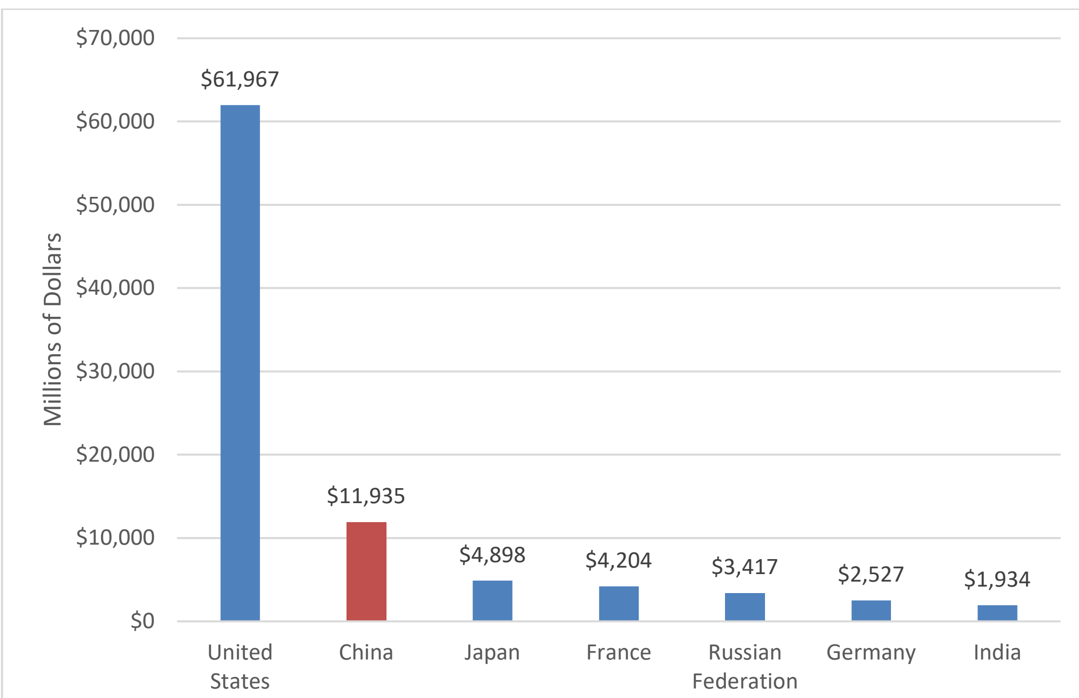
The report is organized as follows. Chapter 2 presents data comparing China's space sector to other spacefaring nations. In Chapter 3, we provide an overview of China's educational system and describe why it is important to understand the development of space talent in China. Chapter 4 discusses the most important research institutions that train China's space workforce. Chapter 5 provides an overview of China's most important SOEs related to space and their relationship to the space industry and educational system, as they are major employers of space talent. Chapter 6 addresses where Chinese students focused on space find jobs after completing their degree programs. Chapter 7 presents the conclusions from each of the preceding chapters.

2. Benchmarking China's Endeavors in Space against Other Countries

This chapter compares China to other spacefaring nations in terms of expenditures on space and human capital. While the rest of the report focuses on China's space talent, this comparison helps contextualize the system for which the talent is being developed.

A. Space Budgets

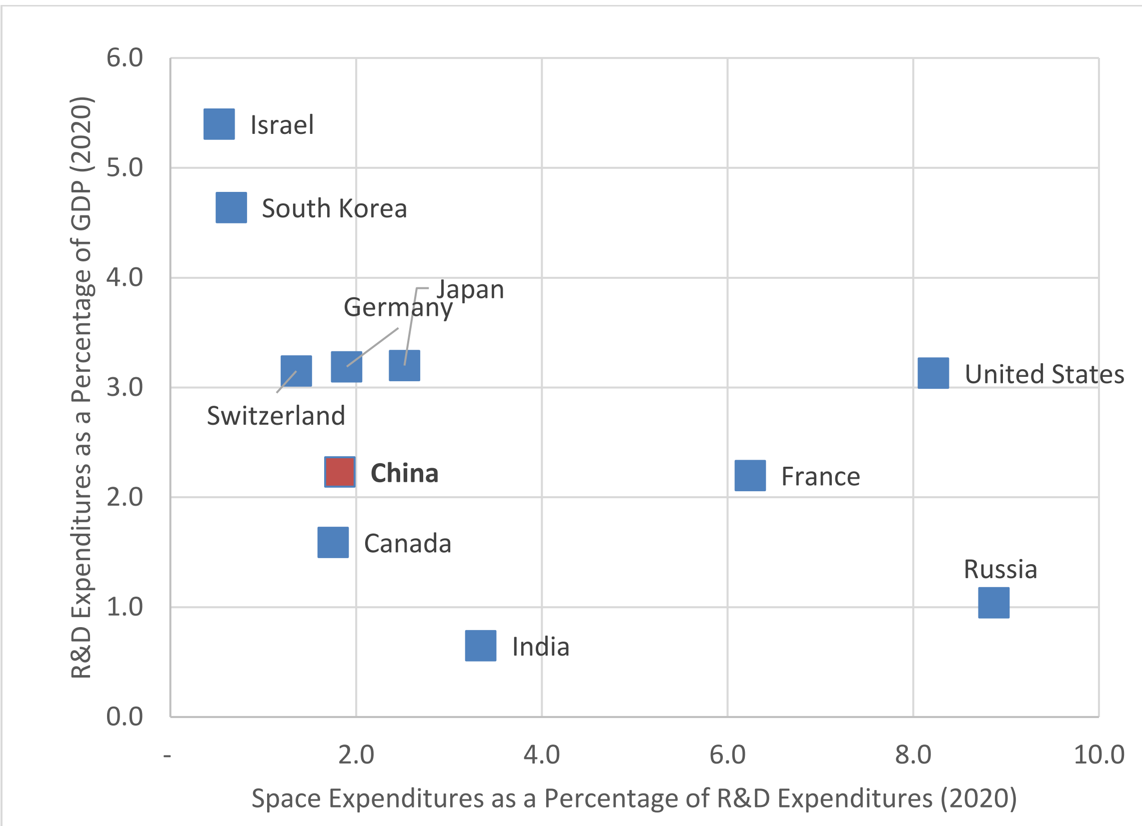
Since 1957, 89 nations have launched at least 1 rocket into space. Many of these countries first accessed space in the 1990s and 2000s (DoD 2022). Of these countries, the United States, China, Japan, France, and Russia have the largest government expenditures on space programs (Euroconsult 2021). China has the second largest expenditures on space, with $11.9 billion in 2021, after the United States (nearly $62 billion; Figure 1).



Source: Euroconsult 2022 – Government Space Programs Report

Figure 1. Government Expenditures on Space in 2021

While the dollar value of government budgets provides some insight into the priority and level of effort governments devote to space, another way to measure the importance a government ascribes to space is to measure the percentage of gross domestic product (GDP) a country devotes to research and development (R&D). R&D expenditures normalized by GDP is often referred to as R&D intensity. An R&D intensity of over 3 percent of GDP is viewed by the policy community as substantial and a measure of the degree to which a nation is investing in innovation (NCSES 2022). Another metric useful for international comparisons regarding space is the percentage of a total expenditures on R&D devoted to space. Figure 1 compares government expenditures on space in 2021. Figure 2 shows the space expenditures as a share of total expenditures on R&D for the largest spacefaring nations. Based on these data, China's space expenditures in 2021 were less than 2 percent of their overall R&D expenditures.



Source: STPI analysis based on government space budgets; OECD data on R&D expenditures and GDP.

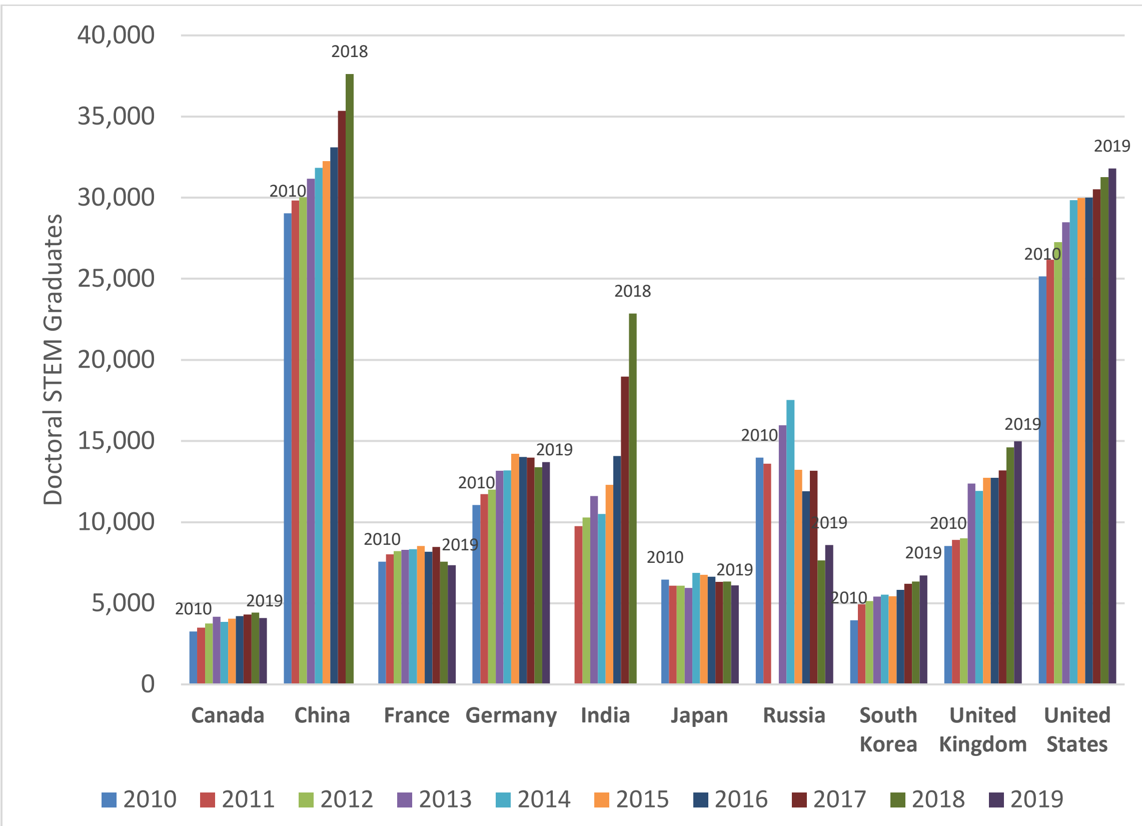
Figure 2. Expenditures on R&D as a Share of GDP versus Space Expenditures Intensity for Selected Countries

B. Global Comparison of Doctoral Degrees Granted in STEM

This section compares awards of STEM doctoral degrees by selected spacefaring nations. STEM doctoral degrees include degrees in the physical sciences, the biological sciences, mathematics, statistics, computer science, agricultural sciences, and engineering (GAO 2013). By this definition, STEM degrees do not include the social sciences;

Appendix B provides more detailed data tables. This section does not focus on space-specific degree fields; we rely on trends in awards of STEM degrees as a proxy for space fields.

Figure 3 shows that between 2010 and 2019, the number of STEM doctoral degrees achieved increased in many spacefaring nations—with particularly sharp increases in China and India. The United States, the United Kingdom, and South Korea reported substantial increases in the number of STEM doctoral degrees obtained as well. STEM doctoral degrees granted in many of the other nations were flat, with Russia reporting the largest overall percentage decline in STEM doctoral degrees awarded between 2010 and 2019.



Source: Science and Engineering Indicators, Table SHED-12

Notes: Data for 2019 downloaded from OECD.Stat education and training database. 2019 data not available for all countries.

Figure 3. Number of Doctoral STEM Graduates from 2010 to 2019 for Selected Countries

We also examined the share of all doctoral degrees that were awarded in STEM fields. Figure 4 shows trends across selected spacefaring nations. The percentage of doctoral degrees awarded in STEM fields is a loose proxy for the potential for innovation in specific science fields and technologies. Over time, these percentages have remained relatively flat for most countries, including China.

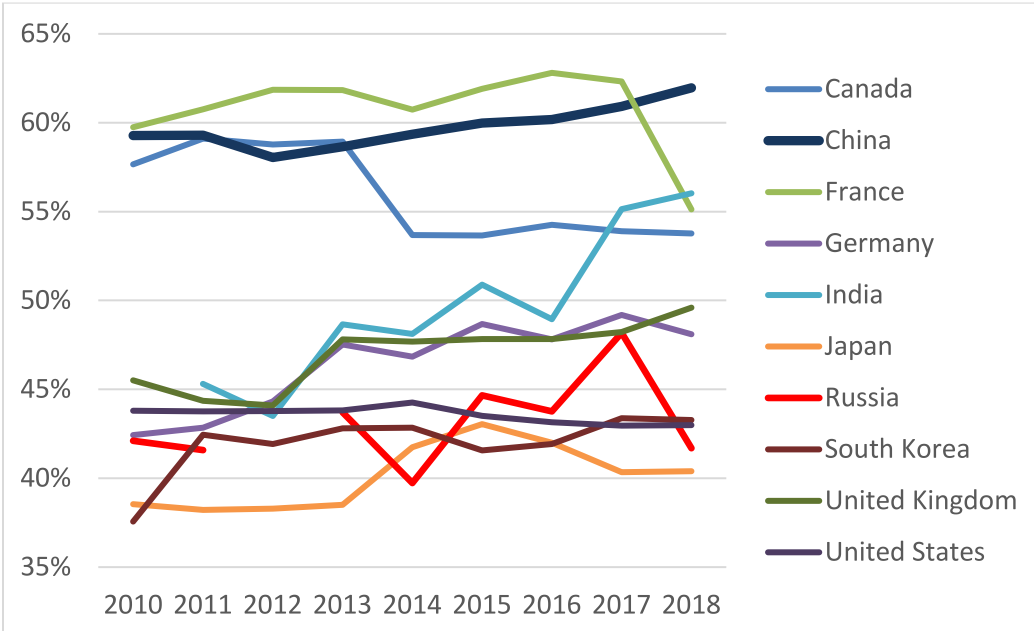


Figure 4. Share of Doctoral Degrees in STEM, 2010–2018

Figure 5 compares the share of STEM doctorates by country for 2018. We found that China had the highest share at 62 percent while the United States and Japan were at the other end at about just over 40 percent.

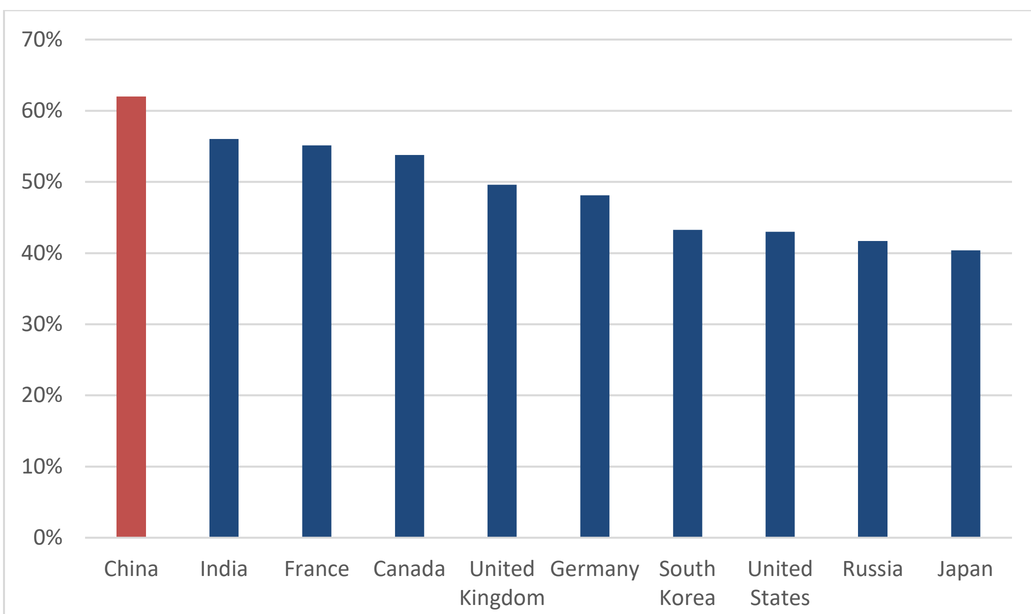


Figure 5. STEM Doctoral Degrees as a Share of All Doctoral Degrees, 2018

Indicators such as space budgets and degrees, which can facilitate international comparisons, do not predict how prominent a nation will be in space but provide measures to better understand the context in which a spacefaring nation operates.

3. China’s Educational System

A. Background

China’s educational system is vast. It encompasses several hundred million students in primary and secondary school, and more than 50 million post-secondary students as of 2020 (Stats.gov 2021). Compared to the United States, China has a much larger system of public education. The overwhelming majority of top universities in China are public universities. At the primary and secondary level, private education has made larger inroads. China has a variety of private international schools, though most of the country’s top primary and secondary schools remain public.

Students advance in China’s educational system largely based on tests. The *zhongkao* (中考，secondary school entrance examination), and the more well-known *gaokao* (高，university entrance examination) are two of the most important factors in a student’s success. However, the *gaokao* is considerably more important than the *zhongkao*. This singular emphasis on examinations has begun to change in recent years as universities have taken a more holistic approach to applications. Nonetheless, the importance ascribed to examinations remains largely the same.

Given the importance of the *gaokao* exam, families spend substantial amounts of money and time helping students prepare. Over the past 10–15 years, this has contributed to an educational competition, with parents spending increasing amounts of money on tutors and other academic preparation. The Chinese government has begun to crack down on this competition, putting into effect regulations restricting private and online education in an attempt to ensure a more level playing field for Chinese students (GT Staff Reporters 2021).

The Chinese central government is slowly acknowledging certain flaws in the *gaokao* system, in particular a tendency towards rote memorization rather than creative problem-solving and independent thinking. In recent years, a handful of elite Chinese universities have partnered with foreign universities, and foreign universities have opened campuses in China. These include Xi’an Jiaotong-Liverpool University, Duke Kunshan University (a partnership between Duke and Wuhan University), the University of Nottingham Ningbo China, and New York University Shanghai. These universities account for a very small minority of Chinese college students, but are nonetheless seen as a step towards a more balanced higher educational curriculum.

B. Post-Secondary Education

According to the *China 2020 Statistical Yearbook*, the country graduated approximately 28 million secondary school students in 2020, and admitted 9.7 million students into "regular undergraduate institutes of higher education." An additional 2.7 million enrolled in online courses, and a further 3.6 million enrolled in "adult institutes of higher education." China's post-secondary educational system tries to be egalitarian, providing opportunities based on merit. However, because there are few highly ranked universities, enrollment slots are extremely competitive. In 2019, the overall admission rate among takers of the *gaokao* was 81 percent, while the admissions rate for the elite "985" and "211" universities—groups comprising the country's 150 best universities—was 2.1 percent and 3.1 percent, respectively (Xi'an Jiaotong University 2019).

Prior to taking the *gaokao*, students select three universities to which they wish to apply. Each university has a minimum required score, with the score varying by province, and with a certain number of points given for ethnic minorities, which also varies by province. If a test-taker scores higher than the minimum required score for the individual's first-choice university, the test-taker may be given a spot at that university. If the individual does not reach the minimum score, the individual will be passed to the individual's second-choice, and so on. If the student does not score the minimum for any of the student's three chosen schools, the student is not admitted, but may retake the *gaokao* the following year. There is no limit to the total number of times one can take the exam, but it can be taken only once per year during the early June period.

In terms of test material, China began a reform of the *gaokao* in 2019, known as the "3+1+2 system." This system was first introduced in a handful of provinces. The "3+1+2" refers to the three compulsory subjects, namely Chinese, mathematics, and a foreign language; one subject chosen is between physics and history; and two elective subjects are drawn from chemistry, biology, politics, and geography. By 2024 the "3+1+2 system" will be in place nationwide, replacing the former "3+3" system that included the same three compulsory courses, and three electives out of the subjects mentioned above.

The generation of the Chinese leadership who attended university from 1966–1976 did not take the *gaokao*, as it was suspended during the Cultural Revolution. Many of the university entrants from this period were not necessarily admitted based on merit. The *gaokao* administered in 1977 is considered by far the most difficult, because so many smart, but poorly-connected students took it following its reinstatement.[1] President Xi Jinping entered China's top university, Tsinghua University, in 1976, the last year when admission was not based on test scores. China's Premier Li Keqiang entered the country's

[1] The 1977 Gaokao saw 272,971 university admissions out of 5.7M test-takers

second-best university, Peking University, in 1977, besting tens of millions of his countrymen in that year's exceptionally challenging *gaokao*.

Before starting their studies, all first-year students in China must first undergo 2 to 3 weeks of compulsory military training before the beginning of the academic year so they can develop a sense of "patriotic enthusiasm" (*The Economist* 2017). After this brief period of military training, students join a "unit" (班) at their respective universities. In addition to military training, students in a unit take classes together. They will stay in the same unit together for the entire 4 years of their undergraduate education. This arrangement extends even to the largest universities. General education courses required for all majors include English, advanced mathematics, politics and ideology, and physical education, among others. Due to the rigor of China's secondary education and the *gaokao*, the prevailing sentiment in China is that undergraduate is considerably less stressful than the final 1 to 2 years of high school. Indeed, in 2018, China's Minister of Education Chen Baosheng proposed an end to what he called the "exhausting high school, carefree university" paradigm (Zhang 2019).

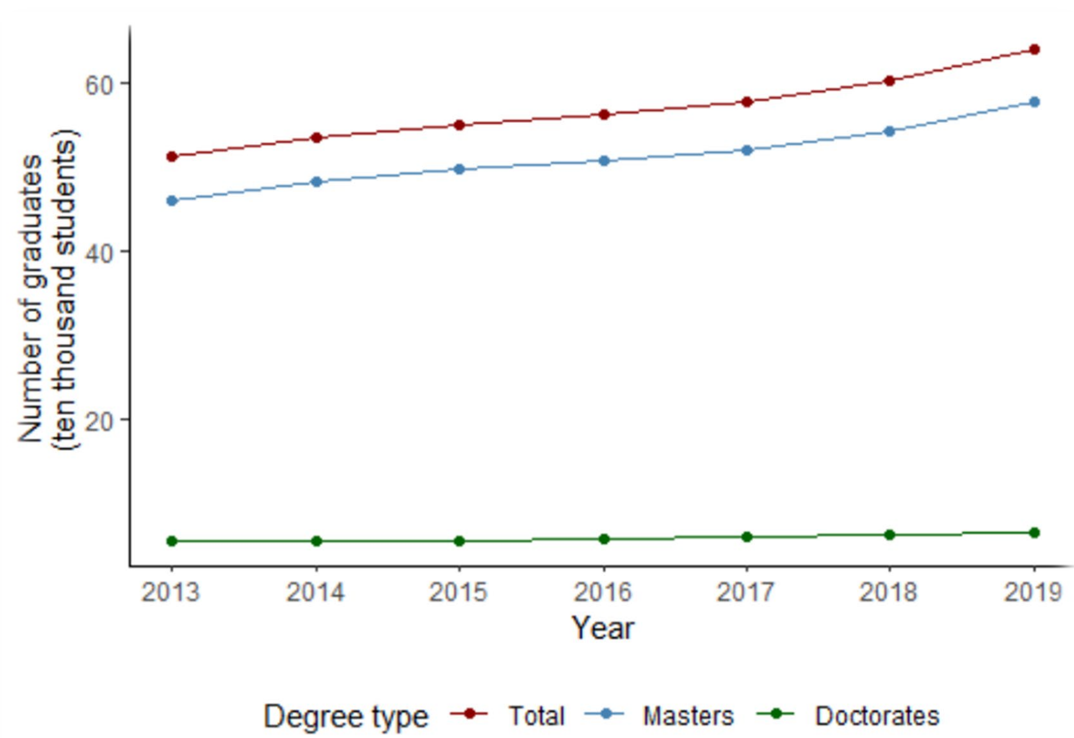
For undergraduate students, the average course load is 7 to 8 courses per semester, averaging 2 to 3 hours per course per week. Grades tend to be primarily based on midterm and final examinations, with minimal opportunity for feedback during the semester. When sampling several dozen comments from Chinese students who have studied both in China and abroad, posted on the websites *Quora* and *Zhihu* (Chinese version of Quora), the overwhelming sentiment was that Chinese university courses are easier than Western university courses, due largely to the emphasis on rote memorization rather than critical thinking.

The relatively straightforward nature of China's undergraduate education program (compared to that of high school) is reflected in the very high graduation rates among Chinese undergraduates. At the country's top universities, around 90 percent of students graduate on time, and at less selective universities, the figure often exceeds 95 percent. This high graduation rate is due to a number of factors. Pressure on students can lead to psychological breakdowns if they are not allowed to graduate. Due to difficulties in changing majors or transferring universities, if a student is struggling in a given course of study, rather than changing to another department or university, the student is more likely to simply be waived through. Such issues are being recognized by the Ministry of Education; however, change has been slow (Ministry of Education 2021).

C. Graduate Studies

For students seeking admission into postgraduate study, many opportunities are available. A typical master's programs lasts 2 to 3 years, while typical PhD programs last 3 to 5 years (PRC Embassy Nepal 2004). For entry into PhD programs, students require several letters of recommendation from existing scholars in their chosen field, as well as being "patriotic, moral, ready to serve the country's construction and well-grounded in basic theory and have solid and systematic knowledge and related techniques and methods of their respective fields." As of 2020, approximately 3.1 million students were enrolled in graduate school programs in China, of which 2.7 million were working towards a master's degree, and 466,000 were working towards a doctorate.

The total number of graduates with a master's or doctoral degree has increased over time from approximately 510,000 graduates in 2013 to 640,000 graduates in 2019, with master's degree holders accounting for approximately 90 percent of all post-graduate graduates (Figure 6).



Source: China Statistical Yearbooks.

Figure 6. Number of Graduates by Degree Type by Year, All Fields, 2013 to 2018

China announced a series of reforms of the country's postgraduate educational system in 2020. These included having a "high-level postgraduate education system basically in place" by 2025, and having "generally developed into a leading country for postgraduate education with Chinese characteristics" by 2035 (Xinhua 2020). China will increase investment into doctoral research, in particular providing support towards basic R&D for core technologies in key fields. The reforms were announced by three of China's most powerful institutions, namely the Ministry of Education, Ministry of Finance, and the National Development and Reform Commission (NDRC).

4. Chinese Research Institutions and Research Productivity

This chapter describes the top Chinese research institutions for the space sector as well as assesses the academic productivity of Chinese space researchers.

A. Top Chinese Research Institutions

The top 20 Chinese research institutions by number of total aerospace publications are listed in Table 1. Researchers from the Chinese Academy of Sciences (CAS) accounted for 22.8 percent of all publications, followed by those from the University of the Chinese Academy of Sciences at 7.1 percent, Wuhan University at 4.6 percent, Peking University at 4.4 percent, and Tsinghua University at 3.8 percent followed.

Table 1. Top 20 Chinese Research Institutions by Total Number and Percentage of Aerospace Publications That Had at Least One Author with That Affiliation

Institution	Total Number of Publications	Percent of All Publications
Chinese Academy of Sciences	18,599	23%
University of the Chinese Academy of Sciences	5,789	7%
Wuhan University	3,772	5%
Peking University	3,586	4%
Tsinghua University	3,125	4%
Beihang University	2,928	4%
Nanjing University	2,483	3%
Harbin Institute of Technology	2,256	3%
Beijing Normal University	2,236	3%
University of Science and Technology of China	2,095	3%
National University of Defense Technology	2,059	3%
Northwestern Polytechnical University	1,918	2%
Xidian University	1,711	2%
Nanjing University of Aeronautics and Astronautics	1,669	2%
Shanghai Jiaotong University	1,547	2%
Beijing Institute of Technology	1,314	2%
Sun Yat Sen University	1,163	1%
Zhejiang University	975	1%

Institution	Total Number of Publications	Percent of All Publications
China University of Geosciences	943	1%
University of Electronic Science and Technology of China	938	1%

Source: Combined list curated from Web of Science Core Collection, Web of Science Chinese Science Citation Database, and Scopus

The top 20 Chinese research institutions, as measured by the average number of citations received per publication per year, can be found in Table 2. Specifically, publications that had at least one researcher affiliated with Wuhan University received, on average (± standard error (SE)), 4.1 (± 0.13) citations per year followed by Peking University at 4.0 (± 0.11) citations per year, Beijing Normal University at 3.5 (± 0.2) citations per year, Tsinghua University at 3.5 (± 0.22) citations per year, and Nanjing University at 3.3 (± 0.20).

Table 2. Top 20 Chinese Research Institutions as Measured by Average Number of Citations Received per Publication per Year

Institution	Average Number (± SE) of Citations per Publication per Year
Wuhan University	4.1 (± 0.13)
Peking University	4.0 (± 0.11)
Beijing Normal University	3.5 (± 0.20)
Tsinghua University	3.5 (± 0.22)
Nanjing University	3.3 (± 0.20)
Northwestern Polytech University	3.1 (± 0.19)
University of the Chinese Academy of Sciences	3.1 (± 0.23)
Chinese Academy of Sciences	3.0 (± 0.08)
Xidian University	3.0 (± 0.11)
China University of Geoscience	3.0 (± 0.16)
University of Science and Technology of China	2.7 (± 0.11)
University of Electronic Science and Technology of China	2.5 (± 0.13)
Harbin Institute of Technology	2.4 (± 0.15)
National University of Defense Technology	2.4 (± 0.08)
Zhejiang University	2.2 (± 0.12)
Beihang University	2.2 (± 0.07)
Shanghai Jiao Tong University	2.1 (± 0.09)
Shandong University	2.0 (± 0.12)

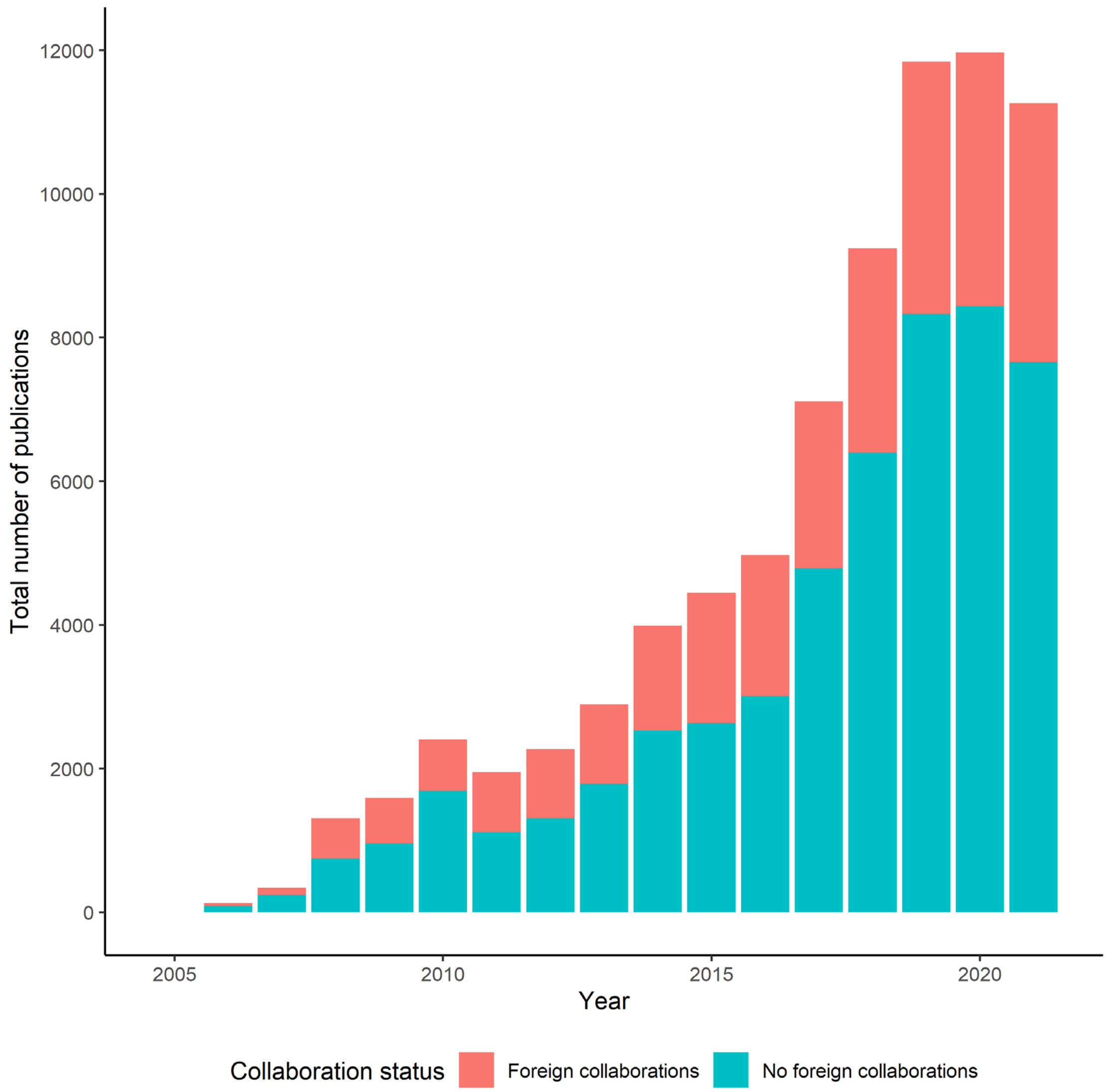
Institution	Average Number (± SE) of Citations per Publication per Year
Beijing Institute of Technology	2.0 (± 0.09)
Nanjing University of Aeronautics and Astronautics	1.6 (± 0.06)

Source: Combined list curated from Web of Science Core Collection, Web of Science Chinese Science Citation Database and Scopus

B. Foreign Collaborations at Chinese Space Research Institutions

In the space publication dataset described in Appendix A, we found 81,261 publications with at least 1 author affiliated with a Chinese institution. The number of aerospace publications by Chinese researchers has increased every year since 2005, with the exception of 2011 and 2021 (Figure 7). The highest number of publications was observed in 2020 (11,961) followed by 2019 (11,793); the lowest number of publications was observed in 2005 (2), followed by 2006 (126).

Overall, one-third of publications between 2005 to 2021 had at least one or more foreign collaborators, and two-thirds did not have any foreign collaborators (Figure 7). The percentage of publications with 1 or more foreign collaborators has varied over time from a high of 50 percent in 2005 (1 of the 2 publications that year had a foreign collaborator) to a low of 28 percent in 2007 when 96 of the 243 publications had 1 or more foreign collaborators.

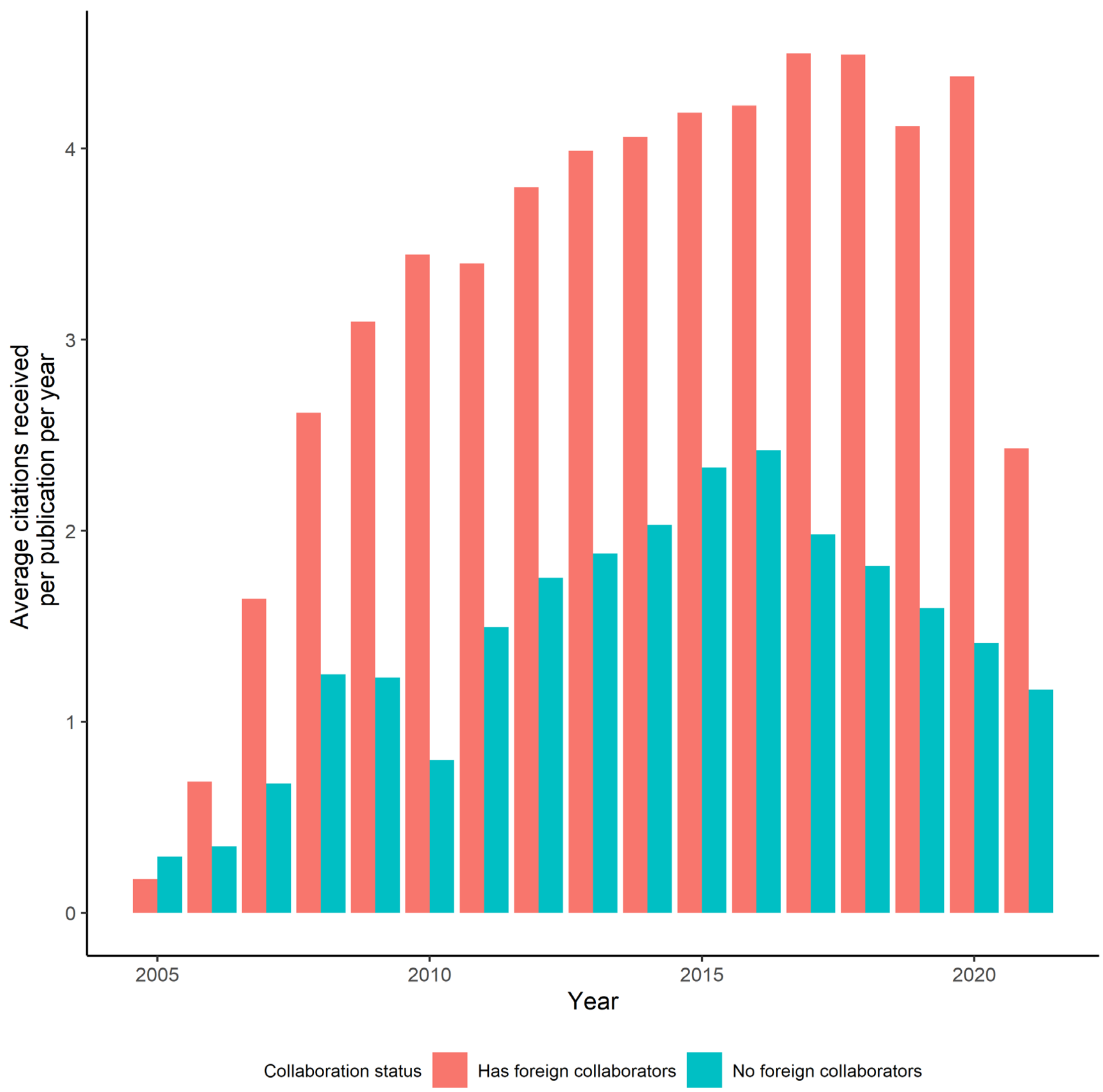


Source: Analysis of Web of Science Space Publications

Figure 7. Number of Space Publications over Time with Foreign Collaborators

When we examined the top Chinese research institutions publishing in space based on citations received, we found that the average number of citations received per publication per year was 2.4 (standard deviation (SE) of ± 0.03). We further assessed if the average citation rate of publications with at least one foreign collaborator was higher or lower than without foreign collaborators. When taking into consideration whether the article was written with a foreign collaborator, the average (± SE) citations received per year for publications without foreign collaborators was 1.6 (± 0.02) and 3.9 (± 0.08) for publications with foreign collaborators (Figure 8). Results from the generalized linear mixed-effects model showed that after accounting for random effects from when a publication was published, publications that had foreign collaborators received, on average, 2.3 times more citations than publications that did not have any foreign collaborators ($p < 0.001$).

Upon interrogating the data, we found that the space publications set was dominated by astronomy or astrophysics publications. We repeated the analysis when removing the astronomy/astrophysics publications and found that the foreign collaboration findings still remain. The average number of citations of non-astronomy publications without foreign collaborators was 1.6 (± 0.02) and 3.5 (± 0.06) for publications with foreign collaborators. See Appendix C for details of this analysis.



Source: Analysis of Web of Science Space Publications

Figure 8. Average Numbers of Citations Received per Publication per Year through Time and by Collaboration Status

These findings are consistent with other studies that have shown that foreign collaborations have significantly higher citation rates than those that do not (Narin et al. 1990; Glanzel and de Lange 2002; Goldfinch et al. 2003; Tang and Shapira 2012). For instance, a 2002 study assessing the impact of bilateral international and multinational biomedical research publications relative to domestic publications found that for China, the observed number of citations was approximately 2.8 times higher in bilateral international publications and 7 times higher in multinational publications relative to domestic publications. Another study found that Chinese nanotechnology research publications with international collaborations had significantly higher impact, as measured by citations, than those that did not (Tang and Shapira 2012).

C. Top Ten Foreign Collaboration Countries in Space

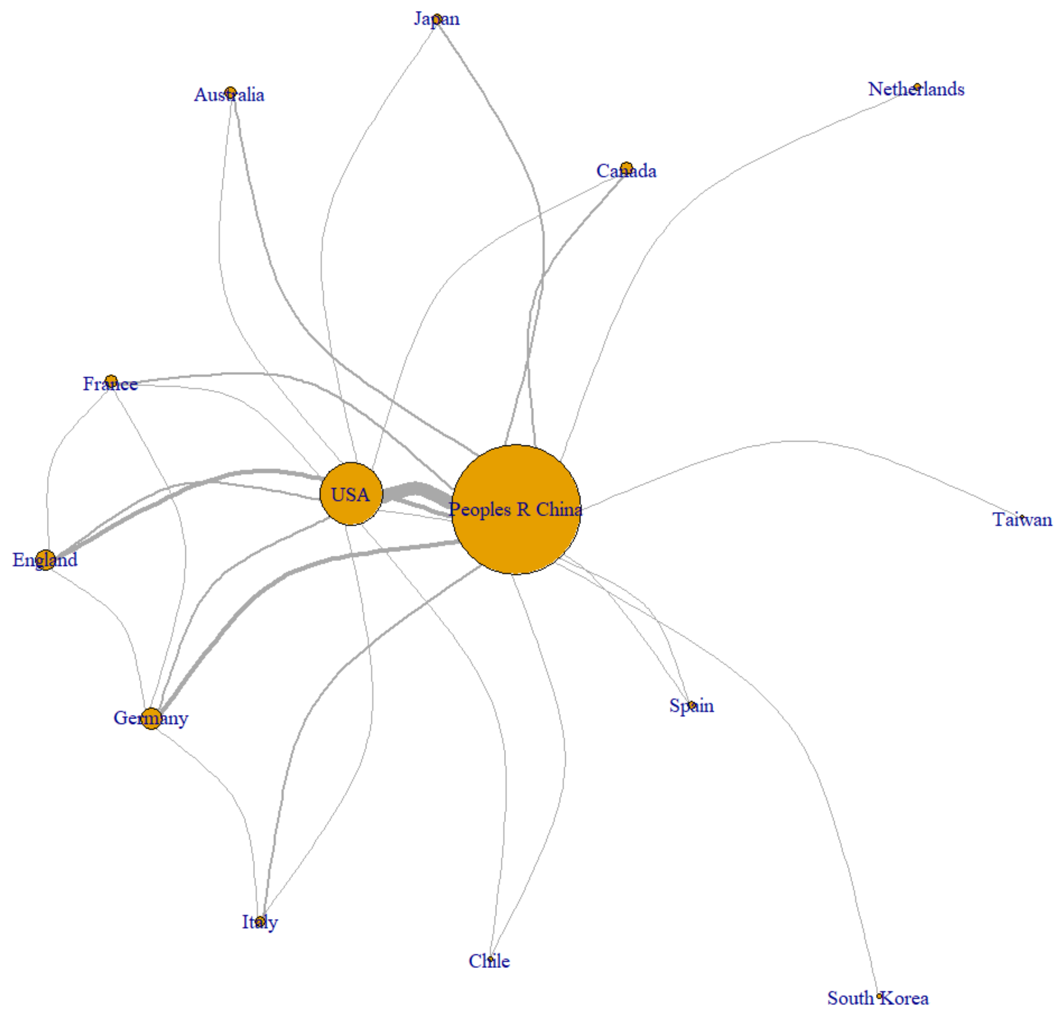
The top 10 foreign countries with whom Chinese researchers collaborated by number of total publications were the United States followed by Germany, the United Kingdom, France, Canada, Australia, Italy, Japan, Spain, and the Netherlands (Table 3). Overall, 16 percent of all publications with a Chinese research institution-affiliated researcher also had at least one researcher from the United States; 6 percent had at least one researcher from Germany; 5.4 percent had at least one researcher from the United Kingdom; 3.5 percent had at least one researcher from France; and 3.5 percent had at least one researcher from Canada.

Table 3. Top Foreign Collaborators, by Number and Percentage of Total Publications, 2005–2021

Country	Number of Publications	Percentage of All Publications
United States	12,988	16%
Germany	4,633	6%
United Kingdom	4,391	5%
France	2,861	4%
Canada	2,830	4%
Australia	2,552	3%
Italy	2,393	2.9%
Japan	2,245	2.8%
Spain	1,791	2.2%
Netherlands	1,634	2.0%

Source: Analysis of Web of Science Space Publications

When considering pairwise collaborations across countries, we found 45 countries with which China had 100 or more collaborative publications, and 13 countries with which China had 1,000 or more collaborative publications (Figure 9).



Source: Analysis of Web of Science Space Publications

Note: Node size varies by total number of publications attributed to each country. Edge size varies by total number of collaborative publications between countries.

Figure 9. Social Network Analysis of Countries That Have More than 1,000 Collaborative Space Publications with at Least One Chinese Institution-Affiliated Researcher

The United States and China are clearly central players in foreign collaborations of space publications. From these social network analyses, we can also see which other countries are collaborating with each other. For example, we see that in addition to China, Germany also had 1,000 or more collaborative space publications with France, Italy, the United States, and the United Kingdom.

5. China's Space Industry

A. Introduction

This chapter describes the Chinese space industrial sector because it provides important context for China's space ecosystem. One would expect that Chinese space industries, companies, and SOEs will be the main employers of China's space talent.

As of 2022, there were at least 100 commercial space companies in China (European Space Agency 2022). The number is considerably larger if the definition of "space company" is extended to include component manufacturers and service providers such as very-small aperture antennas (VSATs), satellite service providers (e.g., companies that specialize in in-flight connectivity via satellite), and companies specializing in advanced materials (alloys, carbon fiber, etc.).

Despite the number of space companies, most of China's major space initiatives are likely to continue to be conducted by the major space SOEs, primarily CASC. However, there is likely to be a potential scope for commercial involvement. At the annual Two Sessions political conference in Beijing in March 2022, the Chief Designer of China's Manned Space Program, Zhou Jianping, noted that "when our space station is completed and running, we will actively encourage the private sector to engage in China's manned space program in various ways" (Sun and Cao 2022). However, the space station is being built largely by CASC and its subsidiaries. We expect that the major space SOEs will construct most of the spacecraft, equipment, and launch vehicles for China's International Lunar Research Station (ILRS), but that Chinese commercial space companies are likely to have some smaller roles.

B. China's Space State-Owned Enterprises

China's space sector is dominated by several major SOEs. Together, they employ several hundred thousand people who are engaged in the space sector. All of China's major space programs, including the development of launch vehicles and satellites, space stations, and space exploration missions are led by the space SOEs, primarily CASC. CASC manufactures about 50 rockets and several hundred satellites a year. CASIC, the other major space SOE, is building similar capabilities.

1. China Aerospace Science & Technology Corporation (CASC)

CASC is the largest space SOE by a wide margin; most of its roughly 180,000 employees are involved in some space industry activity (Craft 2022a). The company was founded in 1999 when the former China Aerospace Corporation was split into CASC and CASIC. CASC is incorporated as a holding company with more than 100 subsidiaries. At the top is corporate CASC, which may have several thousand employees.

The largest subsidiaries typically have more than 10,000 employees. They also usually have 10 or more second-tier subsidiaries. Notable first-tier subsidiaries include the China Academy of Launch Vehicle Technology (CALT, also known as the CASC 1st Academy), China Academy of Space Technology (CAST, also known as the CASC 5th Academy), and the Shanghai Academy of Spaceflight Technology (SAST, also known as the CASC 8th Academy). First-tier subsidiaries tend to either be focused on a technology vertical, in which case they would be based in Beijing (CALT with rockets, CAST with satellites), or are more diversified, and may form a regional industrial base (SAST in Shanghai, the Sichuan Academy of Aerospace Technology also known as CASC 7th Academy in Chengdu).

Second-tier subsidiaries of CASC tend to be more specialized with hundreds to a few thousand employees. Examples include the 812th Academy of CASC, a SAST subsidiary focused on automation technologies related to satellite manufacturing, among other things.

CASC is the lead contractor for most of the major space programs in China, including the Long March rocket series, the Dong Fang Hong satellite platforms, most of the Chang'e Lunar missions, China's space station, and other projects.

2. China Aerospace Science and Industry Corporation (CASIC)

CASIC was founded in July 1999 as part of the split of China Aerospace Corporation. Because it was part of the same organization as CASC until 1999, there is some degree of overlap, with CASIC manufacturing missiles, rocket engines, communications equipment, and other high-tech products that are crucial to China's civil space program. With approximately 150,000 employees at a corporate level (Craft 2022b), CASIC has a similar structure to CASC, with various academies at different levels of a hierarchy.

Several first-tier subsidiaries are focused on the space sector. The CASIC Fourth Academy, also known as the Sanjiang Group, is the main technical entity in the production of China's solid-fueled rockets, and is also the parent company for most of CASIC's commercial space efforts in Wuhan (Bayuan Dong Ge 2022a). The CASIC Second Academy is based in Beijing and includes subsidiaries devoted to satellite manufacturing, such as the Space Engineering Development Company (SEDC; Bayuan Dong Ge 2022a).

CASIC has significant resources to pour into the space sector; in recent years it has been doing so. The company's decision to invest in space initiatives has partly been based on commercialization—which allows for direct competition with former monopolist CASC in a broader variety of areas—and partly based on high-level support for the space sector in general, which makes space an attractive growth industry for CASIC.

CASIC's space industry initiatives are primarily concentrated in the Wuhan National Aerospace Industrial Base, a megaproject being supported by the Municipal Government of Wuhan and the Provincial Government of Hubei. This includes its launch subsidiary Expace and satellite manufacturing subsidiary SEDC, as well as a variety of downstream activities related to industrial Internet of Things (IoT). Over the coming several years, CASIC is expected to deploy a global low Earth orbit (LEO) narrowband constellation called *Xingyun* and to offer a variety of industrial IoT services as part of its larger CASICloud information technology platform.

3. China Electronics Science and Technology Corporation (CETC)

CETC is one of China's largest SOEs with annual revenues of $55.5 billion in 2021. The company is the prime contractor for China's Space-Ground Integrated Network (天地一体化信息网络), a 2030 Science and Technology Innovation Megaproject designated in the 13th Five-Year Plan. This has led to significant investment into ground- and space-based communications systems, including a handful of test satellites and associated ground networks.

Following the acquisition of the large SOE Potevio in early 2020, CETC may now have more than 300,000 employees. Space is a limited part of its business, but several tens of thousands of employees at CETC are likely to be focused on activities related to space. The company's space-related activities are predominantly focused in Chengdu, Sichuan Province. They include the CETC 9th, 10th, 29th, and 30th Academies, as well as Tian'ao Electronics.

Specific CETC programs include developing a suite of user terminals for China's *Tiantong* mobile satellite constellation and gateways and constellation management software for CASIC's *Xingyun* constellation. Moving forward, CETC is likely to play an important role in the development of ground networks for China's increasingly large in-space infrastructure.

4. China Satellite Networks Limited (China SatNet)

China SatNet was founded in April 2021 as an SOE directly controlled by the State-Owned Assets Supervision and Administration Commission, making China SatNet one of about 100 such companies. Other companies in this group include CASC, CASIC, CETC, and China's three main telecommunications companies. Unlike the other SOEs discussed in this section, China SatNet is a "startup" of sorts, having some several hundred employees. China SatNet is tasked with deploying and operating China's LEO broadband megaconstellation, known locally as the *GuoWang* or National Net(work) project.

C. Commercial Companies

China's commercial space sector has grown rapidly since 2014 when it became possible to set up commercial space companies. There are currently well over 100 commercial space companies in China, of which at least 20 are developing rockets and an additional 15 to 20 are building satellites. Most commercial companies have anywhere from several dozen to as many as several hundred employees. The number of individuals employed by commercial space companies has increased rapidly of late, suggesting that China's commercial space sector is expanding. A 2021 assessment of 23 of China's commercial launch companies found that the total number of employees has increased from 622 individuals in 2019 to 1,624 individuals in 2020, a 161 percent increase in 1 year (Dongfang Hour 2021). The largest commercial space companies include Landspace (launch, about 500 employees), CGSTL (Earth observation, about 750 employees), and Galaxy Space (satellite manufacturing, 300 employees).

Most Chinese commercial space companies were founded by former employees of SOEs. This was particularly true in the first several years of commercialization (2014–2018). More recently, companies have been founded by early-stage employees in first-generation startups. For example, the co-founder and the chief technology officer of Landspace founded Galactic Energy. In some cases, commercial space companies have been founded by tech entrepreneurs or others without a space industry background.

Some commercial space companies have hired entire teams from space SOEs or from space research institutes. For example, Star Vision—a remote sensing startup founded in 2021—hired its entire satellite development team from Zhejiang University's Aeronautics and Astronautics Department, one of the top aerospace programs in China. Other high-profile examples of talent moving from the state to commercial firms include Zhang Xiaoping, a senior engineer from a CASC subsidiary, who moved to Landspace for a salary that was allegedly 10 times more than his previous salary (Chen 2018).

6. Characteristics of China's Professors and Students in Space Disciplines

In this chapter, we analyze the characteristics of professors and students at the top educational institutions with strong departments in disciplines involving space. We start by looking at the profiles of faculty, followed by analyzing the data indicating where students go after completing their degree programs. We round out the chapter by analyzing job advertisements from major employers of space talent, particularly CASC and CASIC.

A. Faculty Profiles at Top Space Institutions

The 10 institutions with strong departments in disciplines involving space included in our analyses are Beihang University, Harbin Institute of Technology, Northwestern Polytechnical University, Nanjing University of Aeronautics and Astronautics, National University of Defense Technology, Tsinghua University, Beijing Institute of Technology, Xi'an Jiaotong University, Shanghai Jiaotong University, and Dalian University of Technology.

A total of 2,171 individual faculty researchers were identified across the 9 institutions,[2] 65.7 percent were male, 13.4 percent female, and 20.9 percent were categorized as *unknown* because they did identify their gender (Table 4). Of these faculty researchers, 47.0% were full professors, 36.1 percent were associate professors, and 16.9 percent were assistant professors (Table 5).

Table 4. Total Number of Chinese Faculty Researchers at Top Space Institutions by Gender

Gender	Number of Faculty Researchers	Percent of Faculty Researchers
Female	288	13%
Male	1,410	66%
Unknown	448	21%

Source: STPI analysis of institution websites

[2] National Defense Science and Technology University had no public information that could be scraped for this study.

Table 5. Total Number of Unique Chinese Faculty Researchers at Top Space Institutions by Academic Rank

Academic Rank	Number of Faculty Researchers	Percent of Faculty Researchers
Assistant Professor	363	17%
Associate Professor	776	36%
Full Professor	1,010	47%

Source: STPI analysis of institution websites

With regard to where aerospace faculty researchers were educated, 83.3 percent received their PhDs from a domestic institution and 16.7 percent from abroad (Table 6). Of those who received their PhDs from abroad, the 5 most popular locations were the United States (27.3 percent), United Kingdom (18.5 percent), Japan (13.3 percent), France (8.2 percent), and Singapore (7.6 percent; Table 7). The top foreign research institutions were Tohoku University (Japan) where 7 aerospace faculty researchers received their PhDs, Delft University of Technology (the Netherlands; 6), the National University of Singapore (Singapore; 6), the Tokyo Institute of Technology (Japan; 6), the University of Tokyo (Japan; 6), the Imperial College of London (the United Kingdom; 5), and Iowa State University (United States; 5).

Table 6. Number of Aerospace Faculty Researchers at Top Space Institutions by PhD Location

PhD Location	Number of Faculty Researchers	Percent of Faculty Researchers
Domestic	1,659	83%
Foreign	332	17%

Source: STPI analysis of institution websites

Table 7. Country of Foreign Institution That Granted PhD

Country of PhD	Number of Faculty Researchers	Percent of Faculty Researchers
United States	90	27%
United Kingdom	61	19%
Japan	44	13%
France	27	8%
Singapore	25	8%
Germany	23	7%
Australia	13	4%
Canada	12	4%

Country of PhD	Number of Faculty Researchers	Percent of Faculty Researchers
Netherlands	9	3%
Russia	9	3%
Sweden	4	1%
Israel	2	1%
Italy	2	1%
South Korea	2	1%
Spain	2	1%
Switzerland	2	1%
Belgium	1	<1%
Norway	1	<1%
Saudi Arabia	1	<1%

Source: STPI analysis of institution websites

The top five domestic research institutions where aerospace faculty researchers received their PhDs were Beihang University, followed by the Harbin Institute of Technology, Northwestern Polytechnical University, Nanjing University of Aeronautics and Astronautics, and Tsinghua University (Table 8). The top five domestic research institutions where aerospace faculty researchers received their master's degree were Northwestern Polytechnical University, followed by the Harbin Institute of Technology, Nanjing University of Aeronautics and Astronautics, Beihang University, and Xi'an Jiaotong University (Table 8). The top five domestic research institutions where aerospace faculty researchers received their bachelor's degree were Northwestern Polytechnical University, Beihang University, Nanjing University of Aeronautics and Astronautics, Harbin Institute of Technology, and Xi'an Jiaotong University (Table 8).

Table 8. Top 10 Institutions Where Faculty Aerospace Researchers Received their PhD, Master's, and Bachelor's Degrees

PhD Institution (number of faculty researchers)	Master's Institution (number of faculty researchers)	Bachelor's Institution (number of faculty researchers)
Beihang University (290)	Northwestern Polytechnical University (285)	Northwestern Polytechnical University (297)
Harbin Institute of Technology (264)	Harbin Institute of Technology (226)	Beihang University (217)
Northwestern Polytechnical University (250)	Nanjing University of Aeronautics and Astronautics (152)	Nanjing University of Aeronautics and Astronautics (196)

PhD Institution (number of faculty researchers)	Master's Institution (number of faculty researchers)	Bachelor's Institution (number of faculty researchers)
Nanjing University of Aeronautics and Astronautics (227)	Beihang University (119)	Harbin Institute of Technology (193)
Tsinghua University (90)	Xi'an Jiaotong University (82)	Xi'an Jiaotong University (96)
Xi'an Jiaotong University (67)	Beijing Institute of Technology (40)	Tsinghua University (51)
Beijing Institute of Technology (50)	Tsinghua University (40)	Beijing Institute of Technology (44)
Nanjing University (41)	Nanjing University (18)	Dalian University of Technology (24)
Dalian University of Technology (28)	Southeast University (18)	Harbin Engineering University (23)
Peking University (22)	Harbin Engineering University (14)	Lanzhou University (23)

Source: STPI analyses of institutions

Note: The number of aerospace faculty researchers who received degrees from the respective institutions is provided in parentheses.

STPI found that 12 aerospace faculty researchers received their bachelor's degrees from a foreign institution of higher education. Among these 12 individuals, 2 graduated from Colorado State University, and 2 from Monash University Melbourne.

We identified more aerospace researchers from Nanjing University of Aeronautics and Astronautics than at any other university (616 total faculty members). Other universities exceeding 100 aerospace faculty members were Beihang University (527), Northwest Polytechnic University (336), Harbin University of Technology (286), and Beijing Institute of Technology (127). For a full list of the number of aerospace faculty researchers by departments and schools within institutions, refer to Appendix B.

B. Institutional Graduate Employment Reports

We analyzed the graduate employment report data across 15 institutions of higher education.[3] These data reflect all graduates, and not just those earning degrees in aerospace or space science. In total, there were 132,956 graduates: 58,162 students

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3 The 15 institutions were Beihang University, Beijing Institute of Technology, Beijing Normal University, Harbin Institute of Technology, Nanjing University, Northwest Polytechnical University, Peking University, Shandong University, Shanghai Jiaotong University, Tsinghua University, University of the Chinese Academies of Sciences, University Science and Technology China, Wuhan University, Xi'an Jiaotong University, and Zhejiang University.

graduated with a bachelor's degree (44 percent), 60,281 students graduated with a master's degree (45 percent), and 14,513 students graduated with a PhD (11 percent; Table 9).

Table 9. Total Number and Percentage of Graduates by Academic Level for All Institutions

Academic Level	Total Number	Percent of Graduates
Bachelor's	58,162	44.0%
PhD	14,513	11.0%
Master's	60,281	45.0%

Source: Academic Institution Graduate Employment Reports

Across these 15 institutions, 48 percent of undergraduate students continued their education domestically, 14 percent continued their education internationally, 28 percent entered into employment post-graduation, and 10 percent had undetermined plans. For master's and PhD graduates, 82 percent and 92 percent respectively, entered into employment post-graduation. A small percentage of master's and PhD graduates continued their education abroad (3 percent and 2 percent, respectively) or domestically (11 percent). A small percentage of graduates had no plans at graduation (Figure 10).

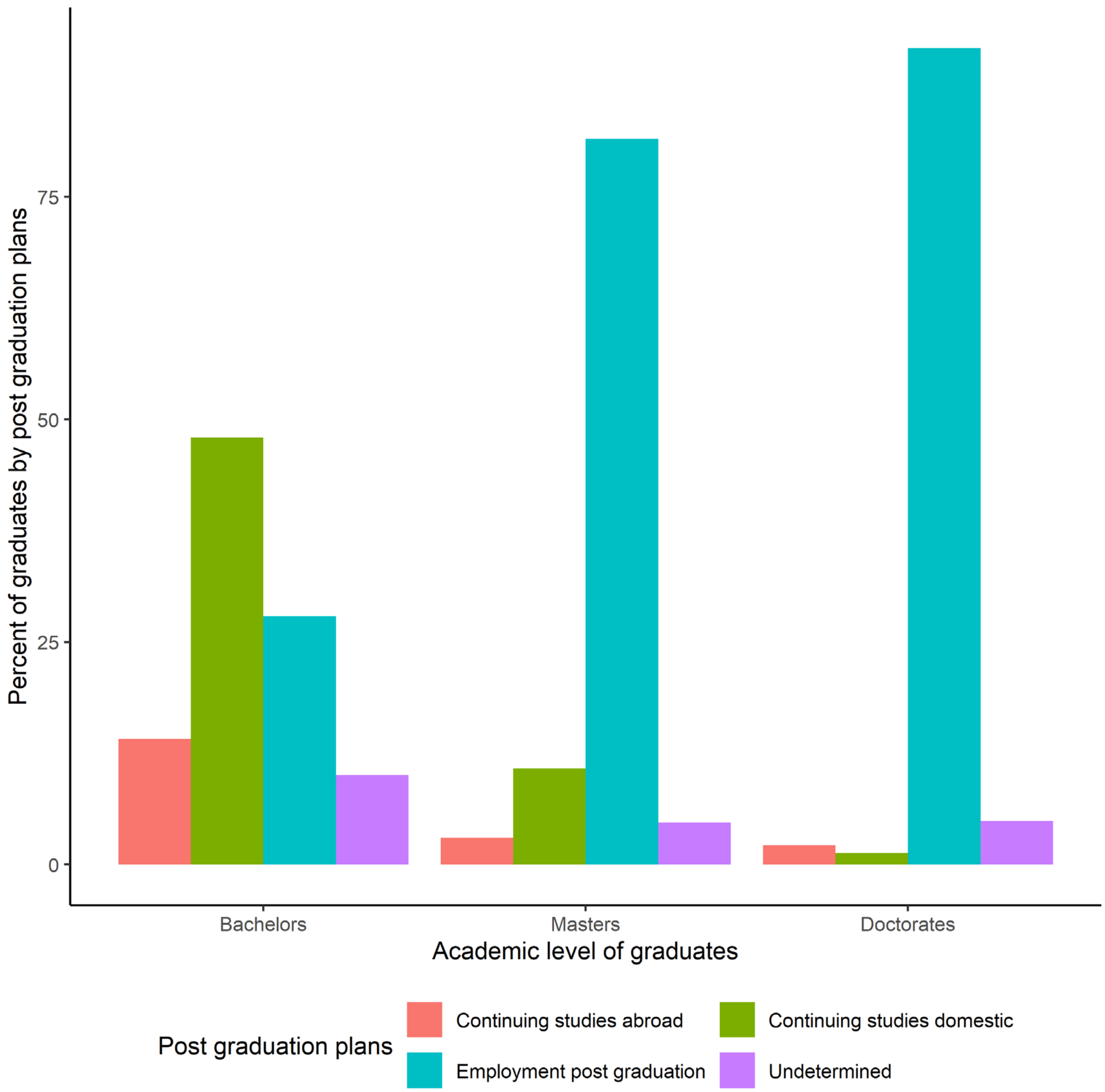

Figure 10. Post-Graduation Plans by Academic Level

Among undergraduates who went into employment after graduation, the top 5 types of employment were those that fell into the *other* category (33 percent),[4] private enterprises (22 percent), SOEs (21 percent), foreign enterprises (9 percent), and scientific research (3 percent; Figure 11). Among master's graduates who went into employment after graduation, the top 5 types of employment were those that fell into the *other* category (28 percent), followed by SOEs (20 percent), private enterprises (16 percent), foreign enterprises (10 percent), and scientific research (8 percent). Among

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[4] *Other* was sometimes used to categorize disciplines reported by individual institutions that were not reported by other institutions. *Other* (i.e., "其他企业") was also a designation reported by these universities.

PhD graduates who went into employment after graduation, the top 5 types of employment were higher education (34 percent), followed by those that fell into the *other* category (19 percent), scientific research (17 percent), SOEs (9 percent), and health care (7 percent).[5]

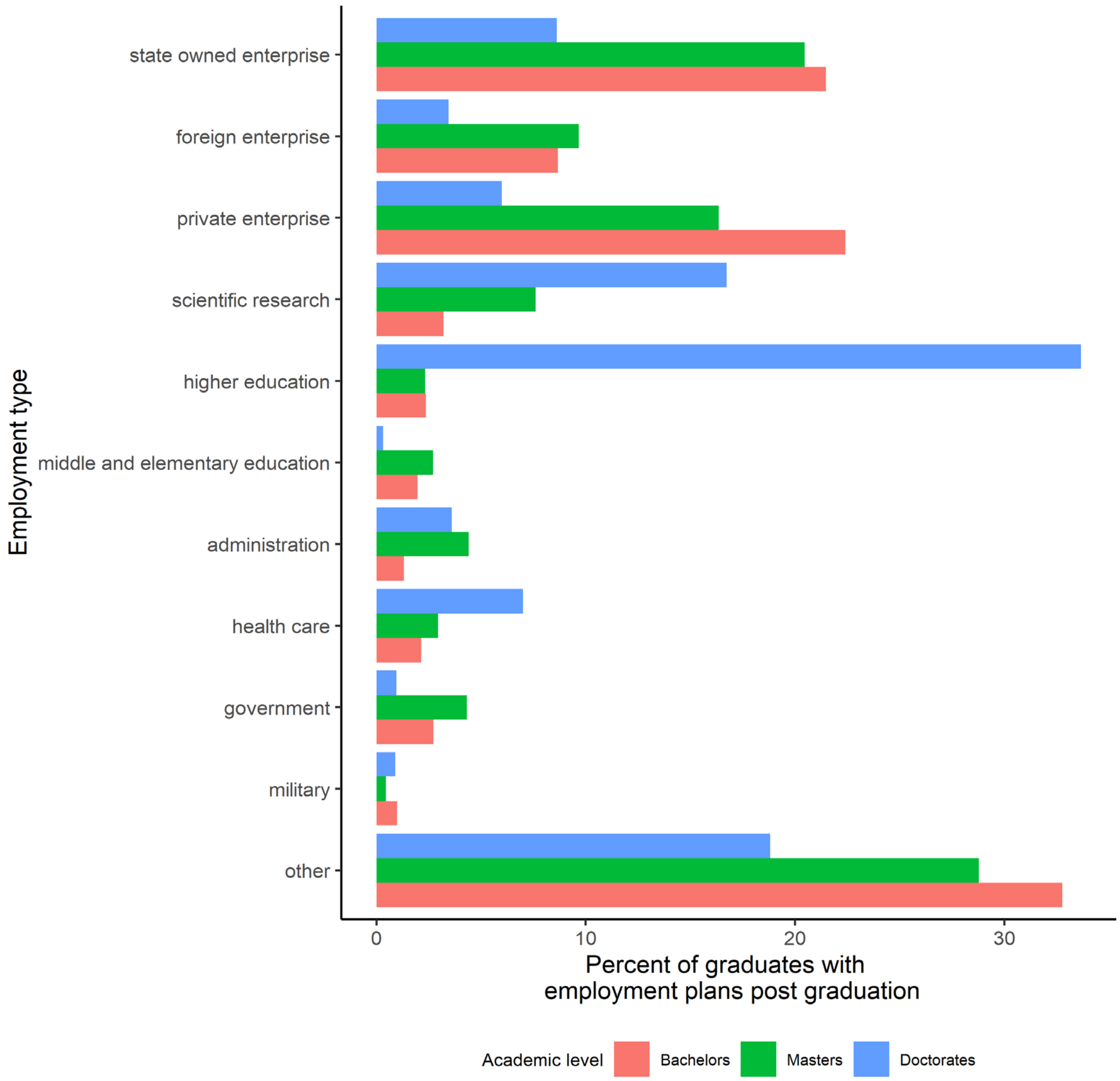

Figure 11. Percent of Individuals with Employment Plans Post Graduation by Employment Type and Academic Level

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5 Employment categories not mentioned include foreign enterprises, middle and elementary education, administration, and military. The percentages of undergraduate, master's, and PhD students entering these fields were all in the single digits.

Surveys of graduating students showed that those students frequently found employment through job fairs held at their universities.[6] For many universities, job fairs are the primary means by which students find employment. For instance, 53 percent of students at Tsinghua University, 58 percent of students at Xi'dian University, and 75 percent of students at Nanjing University found their jobs though job fairs at their respective universities. In addition, these job fairs are typically viewed positively by students. For instance, at Dalian University of Technology, 70 percent and 80 percent of undergraduate and graduate students, respectively, indicated that they had *relatively positive* or *extremely positive* views of their university's job fairs.

Information about job fairs shared by universities in their graduate employment reports indicated that large universities may host several hundred job fairs per year. Many of these job fairs were held even through the COVID-19 pandemic. For instance, during the 2020–2021 school year, Shanghai Jiaotong University held 495 job fairs with participation by 688 large companies, 474 medium-sized companies, and 328 small companies. In 2021, Nanjing Aerospace University held 907 job fairs with participation from 3,134 companies.

Some research institutions surveyed companies to assess their satisfaction with the ability to find and recruit talent at these job fairs. Beijing Normal University found that 93 percent of companies that successfully recruited talent participated in the university's job fairs, 63 percent participated in university-organized presentations, and 61 percent posted recruitment information with the university. Overall, 69 percent of companies noted that they were *satisfied* with the different recruitment methods, and 16 percent were *very satisfied*. The Nanjing University of Aerospace and Astronautics (NUAA) found that 99 percent of companies that attended the university's most recent job fair reported that they planned to return to future job fairs. NUAA reported that more than 78 percent of its students found information about their future employer through these job fairs, many of which were specific to aerospace or related industries.[7]

C. CASC and CASIC Subsidiaries

STPI staff analyzed majors and salaries posted by CASC and CASIC, a major employer in the space sector, to better understand the skills they were looking for. Understanding salaries indicates whether these jobs may be high-paying and more sought after.

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6 This is not specific to aerospace jobs.

7 Other universities are likely also hosting aerospace job fairs, but Nanjing Aerospace University (Nanhang) was one of the few graduation reports to explicitly state this.

1. Required Majors

Of the 81 companies we identified as recruiting at job fairs, 55 listed the majors and disciplines in which they were looking to hire. Table 10 shows the most frequently listed majors sought by CASC and CASIC. The most frequently listed major was computer science, mentioned in 31 of the 55 job announcements (56 percent of all announcements that listed required majors). This was followed by software engineering, mechanical engineering, electrical engineering, and control science and engineering. Aerospace science and technology was the seventh most frequently listed required major. Overall, there were over 300 majors and disciplines listed among the 55 job announcements that featured required majors, ranging from weapons systems, to Marxist theory, to accounting and finance.

Table 10. Top Ten Most Frequently Listed Required Majors for CASC and CASIC Subsidiaries

Required Majors	Number of Companies	Percent of All Companies
Computer Science and Technology	31	56%
Software Engineering	26	47%
Mechanical Engineering	25	46%
Electrical Engineering	21	38%
Control Science and Engineering	20	36%
Electronic Science and Technology	19	35%
Aerospace Science and Technology	18	33%
Automation	14	26%
Information and Communication Engineering	13	24%
Instrument Science and Technology	12	22%
Materials Science and Engineering	12	22%
Mechanics	10	18%

Source: CASC and CASIC Job Announcement Analysis

2. Compensation and Benefits

Thirteen subsidiary profiles provided information on compensation and benefits. These profiles were only for subsidiaries of CASC. Details can be found in Appendix B. All of the companies offered market-competitive salaries based on performance appraisals. The profiles did not expand on the salaries for different advanced degrees, probably because the companies often were hiring across different areas and departments, from accounting to aerospace engineering. For instance, the 806 Institute profile under CASC's Eighth Academy of Aerospace stated that employees are offered competitive salaries, and employees with outstanding performance receive a raise of at least 10 percent every year. This profile also noted that employees with a PhD would receive a two-bedroom apartment, while employees with master's degrees would receive a one-bedroom apartment.

A separate article written by *Bayuan Dong Ge,* that was not part of the netizen's aerospace subsidiary profile series, listed starting salaries at research institutes in China for all recent graduates with master's degrees, but did not specify the degree programs from which these students graduated. The article was not limited to aerospace-related research institutes and companies. However, Table 11 includes only the aerospace companies and institutions that were featured in *Bayuan Dong Ge's* article. The total salary package ranged between 140,000 RMB and 250,000 RMB (approximately $20,880 and $37,280), and the average salary was 195,806 RMB (approximately $29,190) for the 31 research institutes related to aerospace (Table 11). In addition to these salaries, employees may also receive a signing bonus and other bonuses, as well as certain benefits.

Table 11. Salaries for Aerospace Companies and Institutions

Company	Total Salary Package (RMB)
611 Institute - Chengdu Aircraft Design Institute	180,000-220,000
601 Institute - Shenyang Aircraft Design Institute	150,000
615 Institute - Nuclear Power Institute of China	210,000
609 Institute - Xiangfan China Aviation Industrial	180,000-220,000
614 Institute of the Aviation Industrial Corporation of China (AVIC)	200,000
618 Institute - Xi'an Flight Automatic Control Research Institute of AVIC	190,000
612 Institute - China Air to Air Missile Research Institute	150,000
613 Research Institute of Aviation Industry Corporation of China Luoyang	200,000
602 Institute - Aircraft Design Institute	150,000-190,000
Aerodynamics Research Institute, Aviation Industry Corporation of China	150,000
Tianjin Vocational College of Mechanics and Electricity	140,000-150,000
Shanghai Academy of Spaceflight Technology	220,000
CASC 9th Academy	190,000-240,000
CASC 3rd Academy	250,000
CASC 5th Academy	250,000
CASC 2nd Academy	180,000-230,000

Company	Total Salary Package (RMB)
Nanjing Aerospace Changfeng Electronics	200,000
CASIC Aerosun	230,000-280,000
706 Institute in The Second Academy of CASIC	190,000-200,000
CASC 6th Academy	140,000-150,000
CASC 34th Academy	230,000-280,000
CASC 513 Institute	200,000
CASIC 8511 Institute	230,000
Institute of Optoelectronics, Chinese Academy of Sciences	150,000-240,000
Institute of Aeronautics and Astronautics, Chinese Academy of Sciences	180,000-250,000
Institute of Thermal Engineering, Chinese Academy of Sciences	200,000
Shenyang Institute of Automation, Chinese Academy of Sciences	150,000
Institute of Computer Science, Chinese Academy of Sciences	200,000
Institute of Small Satellites, Chinese Academy of Sciences	180,000
Shanghai Institute of Applied Physics	160,000
Shanghai Airplane Design & Research Institute	190,000

Source: Bayuan Dong Ge八院懂哥 [Eighth Academy, Understanding Brother] 2021Employee Information

Of the 81 companies, 27 provided information on the number of total employees within the company and 14 provided information about the percentage of employees who have a master's degree or higher. The percentage of employees with a master's degree or above ranged between 22 to 80 percent of all employees. Seven companies provided information on employees with a doctorate, which ranged from 2 to 7 percent of the total number of employees. The percentage of employees with a PhD is significantly lower than the percentage of employees with a master's degree.

In addition to the information regarding the number of employees with an advanced degree, the netizen often included information on the number of "skilled laborers," "senior professionals," "core technicians," "academicians," "national, provincial and ministerial-level experts," and "experts with government allowances." However, the author did not explain the criteria for each of these categories.

3. Role of the Chinese Household Registration System

In addition to the standard benefits package, some company profiles mentioned providing "household registration declaration for talent introduction." Providing a means of moving an individual's household registration (i.e., 户口 or *hukou*) is a major incentive when attracting top talent because it means that the company will sponsor the employee to work and receive public services in a new locality. The importance of company sponsorship is dictated by China's *hukou* system, which is a government system for registering households by their addresses so as to regulate migration within the country. An individual's *hukou* indicates whether the individual is from a rural or urban locale, and determines where an individual can work, reside, go to the hospital, and where their children can attend school. Although China is reforming the *hukou* system, the system still creates obstacles for individuals attempting to change locales. For instance, if a rural resident finds a job in a city, their rural *hukou* prevents them from accessing urban resident wage levels and restricts their use of public services (Gul and Lu 2011; Jaramillo 2022; Fujita et al. 2004).

On June 1, 2022, the Shanghai Human Resources and Social Security Bureau announced that it will relax its *hukou* system by "granting the permits, or hukou, to non-locals who've graduated from the world's top 50 universities and work in the city" (State Council of the People's Republic of China 2022). Graduates from the world's top 100 universities can qualify for a Shanghai *hukou* if they pay the city's social insurance for 6 months and have full-time jobs in the city (State Council of the People's Republic of China 2022). These reforms are aimed at expanding the talent pool in Shanghai. Even if an individual does not graduate from one of the world's top universities, individuals can earn points based on academic achievements and experience to qualify for a *hukou*. By offering "bonus points" and housing to employees, aerospace companies that want to attract and retain talent are able to reduce or alleviate concerns about the possible restrictions associated with the *hukou* system.

7. Findings

In this study, STPI examined Chinese space talent development by better understanding the research institutions supporting the Chinese space sector, the ability research institutions have to attract and retain talent, and the pipelines that exist for trained graduates to enter the Chinese space ecosystem.

A. China's Top Aerospace Research Institutions

We found that 19 of the top 20 Chinese aerospace research institutions as measured by productivity are the same research institutions as those measured by citation rates. The top aerospace research institutions also include the top six nationally ranked academic research institutions (in order by ranking: Tsinghua University, Peking University, Zhejiang University, Shanghai Jiaotong University, Wuhan University, and Nanjing University). Six other research institutions are ranked in the top 25 (Sun Yat Sen University, Shandong University, Harbin Institute of Technology, University of Science and Technology of China, Beijing Normal University, and Beihang University); another four fall within the top 50 (Northwestern Polytechnical University, Beijing Institute of Technology, University of Electronic Science and Technology of China, and Nanjing University of Aeronautics and Astronautics); and another fall two within the top 100 (Xidian University and China University of Geosciences). We also found that the research institutions considered to be the top in aerospace research have not changed much over the past 25 years.

Based on the data from the graduate employment reports of the 15 institutions that we were able to find and analyze, the total number of master's and PhD graduates from these 15 institutions represents about 1 in 9 of all Chinese post-graduates. Even though these 15 institutions are only a small number of all Chinese academic research institutions, they educate China's top academic talent and appear to have an outsize impact on the aerospace talent trained in China.

B. Foreign Collaborators in Aerospace Research in China

We found that aerospace publications with foreign collaborators had significantly higher citation rates than those that did not have foreign collaborators.

Regarding with whom Chinese researchers are collaborating in aerospace research, we found the top 10 foreign collaborators were the United States, Germany, the United Kingdom, France, Canada, Australia, Italy, Japan, Spain, and the Netherlands. This finding is consistent with other studies that identify China's top foreign collaborators. A 2021 study found that the top six countries with whom China has collaborated across all scientific disciplines over the past 20 years were the United States, Australia, the United Kingdom, Canada, Germany, and Japan (Zhu et al. 2021). Similarly, a 2018 study that examined grants awarded by the National Natural Science Foundation of China between 2006 and 2016 identified the top 15 collaborating countries as the United States, followed by the United Kingdom, Australia, Canada, Japan, Singapore, Germany, France, the Netherlands, Sweden, South Korea, Denmark, Italy, Spain, and Finland (Yuan et al. 2018). Overall, our findings suggest that China's top foreign collaborators in aerospace research are the same as their top collaborators in other scientific disciplines.

C. Aerospace Talent Pipeline

Because China's top aerospace research institutions are the same as China's top academic institutions, students interested in majoring in aerospace or aerospace-related majors apply for enrollment in these institutions through traditional mechanisms such as taking the *Gaokao* for undergraduate admissions or applying to graduate programs.

Our analysis of institutions' graduate employment reports showed that the distribution of graduating students was approximately 45 percent bachelor's, 45 percent master's, and 10 percent PhDs. For undergraduates, approximately 70 percent went on to graduate school, while approximately 30 percent entered into employment post-graduation. For master's graduates, approximately 90 percent entered into employment, and 10 percent continued their education. For doctoral graduates, approximately 95 percent entered into employment, and 5 percent continued on to a post-doctoral position. Of those who graduated with a bachelor's or master's degree and were employed, the top employers were state-owned and private enterprises. Of those who graduated with a PhD and were employed, the top employers were institutes of higher education and scientific research institutes. Data from these graduate employment reports indicate that university career job fairs are the primary mechanism by which students find employment, and for employers to seek out new talent.

The makeup of aerospace faculty researchers across the 9 selected institutions for our web-scraping analysis is similar to findings from Han and Appelbaum (2018) in which the authors conducted a survey of all STEM faculty researchers across the top 25 Chinese academic institutions. We found that 83 percent of aerospace faculty researchers received their PhDs from a domestic institution, while 17 percent received their PhDs abroad. Similarly, Han and Appelbaum (2018) found that 83 percent of their survey respondents received their terminal degrees from domestic institutions of higher education, while 17 percent received their terminal degrees from abroad. We found that among aerospace faculty researchers who received their PhDs abroad, the five most popular locations were the United States, the United Kingdom, Japan, France, and Singapore. Han and

Appelbaum's (2018) findings were largely similar in that they found the top countries from which individuals were receiving their PhDs were the United States, Japan, Germany, and the United Kingdom. The similarities between our analyses of Chinese aerospace faculty researchers and Han and Appelbaum's (2018) analyses of Chinese STEM faculty researchers at large suggest there is nothing out of the ordinary regarding how aerospace talent is attracted to or retained by Chinese institutions of higher education.

D. Attracting and Retaining Aerospace Talent

STPI's analysis of CASC and CASIC and their subsidiaries provide some insight into the types of skills sought by aerospace employers, and what aerospace employers are offering with regard to pay and benefits. We found that computer science was the most sought-after degree or skill, followed by software and mechanical engineering, mechanical engineering, electrical engineering, and control science and engineering. Specific salary ranges were not provided but the subsidiaries noted that pay would be competitive. We found that a standard benefits package often included items such as a furnished apartment, housing subsidy or social security (including five types of insurance and one or two housing funds), and a supplementary medical insurance settlement or signing payment (similar to a signing bonus in the United States: transportation subsidies, meal subsidies, paid time off; job training and professional development opportunities; and bonus points for household registration declaration for talent introduction).

Appendix A.
Space Publications

We identified 112 journals and 51 conference proceedings from Web of Science that focus on space research. We limited our bibliometric analyses to journal articles published in these specific venues. The timeframe was 2005 to February 2022. Of the 454,723 aerospace publications identified using this search criteria, 81,261 (17.9 percent) publications contained at least 1 author affiliated with a Chinese institution. The following analyses are based on this subset of 81,261 publications that contain at least 1 Chinese affiliated author.

We assessed productivity by counting the total number of publications published per year by collaboration status (i.e., a publication had "foreign collaborations" if one or more of the authors had a non-Chinese affiliation, a publication had "no foreign collaborations" if all authors only had Chinese affiliations). We excluded 2022 from this analysis given that only partial publication data were available.

We used citations as a proxy to assess impact. Specifically, we calculated the average number of citations received per publication per year by collaboration status. To assess whether there was a statistical difference in the number of citations a publication received, STPI used a generalized linear mixed-effects model where year was a random effect and collaboration status (publications that had no foreign collaborations were assigned 0, and those that had foreign collaborations were assigned 1) was a fixed effect.

To determine which Chinese research institutions are key in aerospace research, STPI used a two-pronged approach. The first approach quantified key research institutions by the total number of publications that could be attributed to each institution. The second approach quantified key research institutions by the average number of citations received per publication per year. For the first approach, STPI calculated the total number of publications that had at least one author who was affiliated with each research institution. For instance, if a publication had two authors from research institution A and one author from research institution B, the publication would be counted once for both research institutions A and B. Individuals with multiple affiliations were counted once for each of their affiliations. For instance, if an individual listed an affiliation with both research institution A and research institution B, the publication would be counted once for both research institutions. In the second approach, STPI calculated the average number of citations received per publication per year and attributed this based on author affiliations as described in approach one. STPI also excluded 2022 from this analysis given that only partial publication data were available.

To determine the top foreign collaborators of Chinese researchers, STPI identified each author's country affiliation for all publications and calculated the number of total publications that had at least one author from each country. In addition, STPI calculated the percentage of publications from each country that had at least one author from a foreign country.

STPI repeated the above analyses after excluding publications that were categorized as "astronomy or astrophysics" by Web of Science. Because categories are not mutually exclusive, publications that were considered "astronomy or astrophysics" could have been tagged with other categories as well. STPI excluded "astronomy or astrophysics" publications because they frequently contain numerous coauthors given that large, expensive equipment is often used to perform astronomy- or astrophysics-related research, which could have biased our findings (Thelwall 2019).

Appendix B.
Identifying Top Academic Institutions

Web Scraping of Faculty Profiles

To identify the top aerospace academic institutions in China for the web-scraping analysis, STPI compared the top Chinese institutions by total number of publications across three citation databases:

1. The Web of Science Core Collection is a curated database that contains information from over 21,000 journals worldwide and 74.8 million records across 250+ disciplines.
2. Scopus is a curated database containing information from over 26,000 journals and more than 84 million records.
3. The Web of Science Chinese Science Citation Database is a curated database for the Chinese Academy of Sciences containing information from over 1,200 journals, including Chinese language journals, and 5.2 million records starting in 1989 (Clarivate n.d.).

As an initial search to identify the top institutions, STPI used “aerospace” as a keyword search in Scopus and the Web of Science Core Collection. For the Web of Science Chinese Science Citation Database, STPI used the keyword “航天” (i.e., “aerospace”). All searches were limited to publications from 2000 and on. STPI’s use of the Chinese Science Citation Database was primarily to determine whether the top institutions where researchers were publishing in English language journals were the same as those that were publishing in Chinese language journals. The top 25 institutions as identified by number of total publications since 2000 were examined, and the first 10 institutions that occurred in each database were selected for further web scraping and analysis (Table B-1). The 10 institutions included in our analyses were Beihang University, Harbin Institute of Technology, Northwestern Polytechnical University, Nanjing University of Aeronautics and Astronautics, the National University of Defense Technology, Tsinghua University, Beijing Institute of Technology, Xi'an Jiaotong University, Shanghai Jiaotong University, and Dalian University of Technology. The Chinese Academy of Sciences (CAS) was excluded from our list even though it appeared within the first 10 institutions of each database because there are numerous CAS institutes and it was impossible to identify the exact institute for web scraping.

Table B-1. Top 25 Institutions by Total Number of Publications

Scopus	Web of Science Core Collection	Web of Science Chinese
Beihang University	Chinese Academy of Sciences	**Beihang University**
Chinese Academy of Sciences	**Harbin Institute of Technology**	**Harbin Institute of Technology**
Northwestern Polytechnical University	**Beihang University**	**Northwestern Polytechnical University**
Harbin Institute of Technology	**Northwestern Polytechnical University**	**Nanjing University of Aeronautics and Astronautics**
Nanjing University of Aeronautics and Astronautics	**Nanjing University of Aeronautics Astronautics**	Chinese Academy of Sciences
Ministry of Education China	**Tsinghua University**	**National University of Defense Technology**
National University of Defense Technology	**National University of Defense Technology China**	China Astronaut Research and Training Center
Beijing Institute of Technology	**Shanghai Jiao Tong University**	China Academy of Space Technology
Tsinghua University	**Xi’an Jiaotong University**	**Tsinghua University**
Xi'an Jiaotong University	**Dalian University of Technology**	Beijing Institute of Control Engineering
Shanghai Jiao Tong University	University of Chinese Academy of Sciences	**Beijing Institute of Technology**
University of Chinese Academy of Sciences	**Beijing Institute of Technology**	Beijing Space Vehicle General Design Department
Shenyang Aerospace University	Central South University	Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences
Xidian University	Huazhong University of Science Technology	**Xi'an Jiaotong University**
Harbin Engineering University	Tianjin University	**Shanghai Jiaotong University**
University of Electronic Science and Technology of China	Zhejiang University	Beijing Space Electromechanical Research Institute
Zhejiang University	Shandong University	**Dalian University of Technology**
Tongji University	Northeastern University China	Tianjin University
Dalian University of Technology	University of Science Technology Beijing	Beijing Institute of Aerospace System Engineering
Nanjing University of Science and Technology	Chongqing University	Space Science and Applied Research Center of Chinese Academy of Sciences
Huazhong University of Science and Technology	Wuhan University of Technology	Beijing Satellite Environmental Engineering Research Institute
Chongqing University	Peking University	Satellite Technology Research Institute of Harbin Institute of Technology

Scopus	Web of Science Core Collection	Web of Science Chinese
Central South University	Aviation Industry Corporation of China Avic	Beijing Aerospace Automatic Control Research Institute
Nanyang Technological University	Jilin University	China Academy of Launch Vehicle Technology
Air Force Engineering University China	University of Electronic Science Technology of China	Shanghai Institute of Aerospace System Engineering

Sources: Web of Science Core Collection; Web of Science Chinese Citation Database; Scopus
Notes: The top 10 institutions that occur from each list are bolded and used in the web-scraping analysis.

For each of the 10 institutions, STPI manually web scraped information on faculty researchers from every aerospace-related department (e.g., department of aerospace engineering, department of astronautics and aeronautics). For departments such as physics, the department is included when it is a department within an aerospace-specific institution of higher education. For example, information about faculty researchers from the physics department at Beihang University (formerly known as the Beijing Aerospace University) was web scraped but information from the physics department at Tsinghua University was not. The full list of departments web scraped for this study can be found in Table B-2.

Table B-2. Number of Faculty Researchers by Institutions and Departments

Current Institution	Department	Faculty Count
Nanjing University of Aeronautics and Astronautics	*Sum of All Departments*	616
	Aerospace Institute	52
	College of Science	132
	School of Aviation	255
	School of Electronic Information Engineering/ Academy of Integrated Circuit	90
	School of Materials Science and Technology	87
Beihang University	*Sum of All Departments*	527
	School of Aeronautic Science and Engineering	137
	School of Aeronautics	37
	School of Automation Science and Electrical Engineering	33
	School of Computer Science and Engineering	6
	School of Electronics and Information Engineering	99
	School of Energy and Power Engineering	60
	School of Materials Science and Engineering	93
	School of Mechanical Engineering and Automation	43

Current Institution	Department	Faculty Count
	School of Physics	19
Northwest Polytechnical University	*Sum of All Departments*	336
	School of Aeronautics	151
	School of Astronautics	92
	School of Propulsion and Energy	93
Harbin Institute of Technology	*Sum of All Departments*	286
	School of Astronautics	286
Beijing Institute of Technology	*Sum of All Departments*	127
	Flight Control Department	15
	Flight Equipment Engineering	37
	Institute of Advanced Structure Technology	1
	Launch and Propulsion Engineering	26
	Physics Department	46
	School of Aerospace Engineering	2
Xi'an Jiaotong University	Sum of All Departments	82
	Aerospace Engineering	33
	International Applied Physics Center	4
	Mechanical Engineering	37
	Physics Research Teaching Center	8
Tsinghua University	*Sum of All Departments*	80
	Department of Aeronautical and Astronautical Engineering	27
	Department of Engineering Mechanics	53
Shanghai Jiaotong University	*Sum of All Departments*	53
	School of Aeronautics and Astronautics	53
Dalian University of Technology	*Sum of All Departments*	45
	School of Aeronautics and Astronautics	45

Source: STPI Institution Analysis

STPI collected information on faculty researchers from both English and Chinese language sites of the relevant departments at each of the 10 institutions. Data collection was limited to faculty researchers because they engage in both research as well as teaching. Specifically, data were gathered for full professors (教授*jiaoshou*), associate professors (副教授*fu jiaoshou),* and assistant professors (讲授 *jiangshou*). STPI did not collect information for adjuncts, research associates, or engineers, as individuals with these titles may only engage in either research or teaching and would not be able to provide insight on both topics. Details on the information collected can be found in Table B-3.

Table B-3. Information Collected for Each Faculty Researcher, if Available, as Part of the Web-Scraping Process

Variable	Definition
institution_current	name of institution in English
department	name of department in English
name_chinese	name of faculty researcher in Mandarin Chinese
name_pingying	name of faculty researcher in pinyin
email	email address of faculty researcher
gender	one of the following: female, male, unknown
academic_rank	title or academic rank of faculty researcher: one of the following: assistant professor (equivalent to lecturer) associate professor full professor
institution_bachelor	name of institution (in English) where the faculty researcher received his or her bachelor's degree; N/A if none provided
institution_masters	name of institution (in English) where the faculty researcher received his or her master's degree; N/A if none provided
institution_phd	name of institution (in English) where the faculty researcher received his or her PhD degree N/A if none provided
phd_foreign_domestic	indicator on whether the faculty researcher of interest received his or her PhD from a domestic Chinese institution (“domestic”) or from a foreign institution (“foreign”); “N/A” is used to indicate cases when the faculty researcher does not have a PhD or has a PhD but the degree granting institution is unknown
phd_foreign_country	for faculty researchers who received his or her PhD from a foreign institution, the country where the foreign institution resides is listed; “N/A” is used for all other cases (i.e., faculty researchers who received his or her PhD from a domestic Chinese institution; faculty researchers who did not receive a PhD; faculty researchers who received a PhD but the institution is unknown)
orcid	the ORCID of the faculty researcher of interest; “N/A” if none is provided
wos_researcherid	the Web of Science Researcher ID of the faculty researcher of interest; “N/A” if none is provided
thousand_talent_recipient	indicator whether the faculty researcher of interest was a Thousand Talent recipient: 1 indicates he or she was a recipient 0 indicates he or she was not a recipient

Variable	Definition
young_thousand_talent_recipient	indicator whether the faculty researcher of interest was a Young Thousand Talent recipient: 1 indicates he or she was a recipient 0 indicates he or she was not a recipient

Source: University Websites

In total, data were gathered for 2,171 unique faculty researchers among the 10 institutions of higher education. Not all individuals provided their contact information and some provided more than one form of contact.

Institutional Graduate Employment Reports

Since 2014, the Ministry of Education has required Chinese institutions of higher education to report on the quality of employment found by their graduates (Dan 2013). These annual graduate employment reports provide data on enrollment, graduation, and employment as well as information about where students go after completing their degrees. To better understand how talent is attracted and trained for the workforce and where students work after completing their degrees, STPI analyzed the most recent graduate employment reports from 15 institutions for which data were available.[8] For each institution, STPI calculated the total number of graduates by academic degree (i.e., bachelor's, master's, and doctorates) across the institutions; the average percentage of graduates by academic degree as well as the standard deviation; the percentage of graduates continuing their education domestically and abroad post-graduation by academic degree; and the percentage of graduates employed post-graduation by academic degree. For those who go on to employment post-graduation, STPI calculated the total number and percentage of graduates who were employed by academic degree and employment type (i.e., SOE, private enterprise, foreign enterprise, scientific research, higher education, middle and elementary education, administration, health care, military, and other) for all institutions combined as well as the average and standard errors of the percentage of graduates across institutions by academic degree and employment type.

For cases in which the data reported by an institution of higher education did not match that of other institutions or was unable to be calculated based on the data provided,

8 STPI looked for the employment reports from all of the top 20 institutions by rank; 5 were excluded because STPI was unable to find their employment report or their employment statistics were reported in a manner that prevented STPI from directly comparing the institution's employment data to another institution's employment data. The 15 remaining institutions included: Beihang University 2019; Beijing Institute of Technology 2020; Beijing Normal University 2019; Harbin Institute of Technology 2019; Nanjing University 2021; Northwestern Polytechnical University 2019; Peking University 2021; Shandong University 2021; Shanghai Jiaotong University 2020; Tsinghua University 2021; University of Science and Technology of China 2021; University of the Chinese Academies of Sciences 2020; Wuhan University 2021; Xi'an Jiaotong University 2021; and Zhejiang University 2020.

the institution was excluded from that particular analysis. As a result, the number of institutions for each analysis may differ. STPI collected the reports that were publicly available as of January 2021. The most recent public graduation report for these 15 universities ranged from 2019 to 2021.

CASC and CASIC Subsidiaries

In March 2022, a netizen compiled a series of company profiles for CASC and CASIC subsidiaries that were recruiting and hiring for 2022 on the Chinese website, *Zhihu* (www.zhihu.com).[9] This netizen created summary profiles featuring 81 subsidiaries of both CASC and CASIC. These profiles contained information about the respective subsidiary's main focuses, employee data, and required majors—some even included information on employee compensation, benefits, and application requirements. Table B-4. describes the institutions from which CASC and CASIC employees received their degrees. To assess which skillsets were the most sought after, STPI analyzed the list of required majors posted in each job announcement and calculated the number of times a major or discipline was listed (Table B-5). STPI performed a qualitative analysis of compensation and benefits and employee information by identifying common themes across the job announcements.

Table B-4. Institutions from Which Employees of CASC and CASIC Subsidiaries Received Their Degrees

Institution	Department	Number of Faculty Researchers
Beihang University	School of Aeronautic Science and Engineering	137
	School of Aeronautics	41
	School of Automation Science and Electrical Engineering	33
	School of Computer Science and Engineering	6
	School of Electronics and Information Engineering	99
	School of Energy and Power Engineering	60
	School of Materials Science and Engineering	93
	School of Mechanical Engineering and Automation	44
	School of Physics	20

9 The netizen posts information almost exclusively to advise readers on their job search with SOEs and government institutions.

Institution	Department	Number of Faculty Researchers
Beijing Institute of Technology	Flight Control Department	15
	Flight Equipment Engineering	37
	Institute of Advanced Structure Technology	1
	Launch and Propulsion Engineering	26
	Physics Department	46
	School of Aerospace Engineering	2
Dalian University of Technology	School of Aeronautics and Astronautics	45
Harbin Institute of Technology	School of Astronautics	286
Nanjing University of Aeronautics and Astronautics	Aerospace Institute	52
	College of Science	132
	School of Aviation	258
	School of Electronic Information Engineering/Academy of Integrated Circuit	90
	School of Materials Science and Technology	87
Northwest Polytechnical University	School of Aeronautics	148
	School of Astronautics	92
	School of Propulsion and Energy	94
Northwestern Polytechnical University	School of Aeronautics	5
Shanghai Jiaotong University	School of Aeronautics and Astronautics	60
Tsinghua University	Department of Aeronautical and Astronautical Engineering	27
	Department of Engineering Mechanics	53
Xi'an Jiaotong University	Aerospace Engineering	38
	International Applied Physics Center	5
	Mechanical Engineering	43
	Mechanical Structure and Vibration Laboratory	4
	Physics Research Teaching Center	21

Source: STPI Analysis of Subsidiary Data

Table B-5. CASC and CASIC Subsidiaries Employee Information

Subsidiary	Recruitment Unit(s)	Number of Employees in Recruitment Unit	Master's or Higher
CASC 1st Academy	All Units	33,000	22%
CASC 5th Academy	All Units	<20,000	
CASC 8th Academy	All Units	20,000	24%
	812 Institute	600+	50%
	149 Factory	>1,400	23%
	800 Institute	>1,000	40%
	509 Institute	>1,100	70%
	805 Institute	>1,100	80%
	8th Department	>1,000	80%
	811 Institute	>1,100	61%
	804 Institute	>1,800	50%
	803 Institute	>2,000	5% with a Doctorate Degree
	802 Institute	>1,300	54%
	806 Institute	<1,400	
CASC Shanghai Aerospace Industry (Group) Co., Ltd.	All Units	7,327	
CASIC 2nd Research Institute	Beijing Institute of Environmental Characteristics	302	38%
	Beijing Institute of Aerospace Intelligence and Information	<500	
	Beijing Institute of Computer Technology and Application	1,800	60%

Subsidiary	Recruitment Unit(s)	Number of Employees in Recruitment Unit	Master's or Higher
	Beijing General Research Institute of Electronic Engineering	<2,000	
	Beijing Institute of Radio Measurement	<1,800	
CASIC 3rd Research Institute	239 Factory	1,300	22%
	Haiying Safety Technology Engineering Co., Ltd	<400	
CASIC 4th Research Institute	All units	>19,000	
CASIC 2nd Research Institute	The 9th General Design Department	~900	
	Hubei Institute of Aerospace Technology Research on Metrology and Testing Technology	<230	
	Hubei Sanjiang Aerospace Jiangbei Mechanical Engineering Co., Ltd	<1,200	
	Hubei Sanjiang Aerospace Wanfeng Technology Development Co., Ltd.	<1,200	

Sources: (Bayuan Dong Ge八院懂哥 [Eighth Academy, Understanding Brother] 2022p, 2022g, 2022h, 2022i, 2022j, 2022l, 2022m, 2022n, 2022o, 2022f, 2022j, 2022o, 2022s, 2022q, 2022a, 2022s, 2022r, 2022b)

Table B-6. CASC and CASIC Subsidiaries Additional Employee Qualifications and Information

Subsidiary	Recruitment Unit(s)	Other Employee Qualifications
CASC 1st Academy	All Units	7 academicians, more than 20 national experts, 3 winners of the China Skills Award, 4 national skill master studios, 19 national-level candidates for the "Thousand Talents Project," and 41 national technical experts
CASIC 2nd Research Institute	Beijing Institute of Computer Technology and Application	More than 60 master's and doctoral students under training
	Beijing Institute of Radio Measurement	1 academician of the Academy of Engineering, and nearly 400 researchers and senior engineers. There are more than 160 skilled workers including super technicians, senior technicians, technicians, and senior technicians.
CASIC 4th Research Institute	All Units	More than 8,000 scientific and technological talents, more than 20 national-level experts, and more than 230 provincial and ministerial experts
CASC 8th Academy	All Units	More than 2,790 senior professional and technical personnel, and more than 620 skilled personnel above technicians; national and provincial-level experts, provincial and ministerial-level discipline leaders, and various professional and technical personnel total more than 7,000 people
	812 Institute	More than 130 have senior professional titles, 1 is a super technician, 4 enjoy special government allowances from the State Council
	149 Factory	Including more than 600 engineering and technical personnel, 5 people enjoy State Council allowances, 1 national young top-notch talent, 1 Shanghai leading talent, 11 group company level experts and 50 technical experts above the provincial and ministerial level
	805 Institute	Nearly 80% of them have a doctorate or master's degree, including more than 20 provincial and ministerial-level experts, more than 300 technical experts above the chief teacher level, and more than 520 senior professional and technical personnel. There are nearly 100 model chief designers and discipline leaders.
	8th Department	90% of which are professional and technical personnel and more than 450 designers with senior professional titles
	811 Institute	Including more than 700 core technicians, more than 70% of them are under the age of 35; 2 academicians have been introduced flexibly,

Subsidiary	Recruitment Unit(s)	Other Employee Qualifications
		and they have introduced and trained special government officials of the State Council. There are more than 40 provincial and ministerial-level experts such as experts with outstanding contributions to national defense, and leading talents in Shanghai.
	804 Institute	Professional and technical personnel account for 80% of the total employees. There are 43 experts who have special government allowances from the State Council. There are 4 leading talents in Shanghai, 147 academic and technical leaders and reserve experts at all levels, and 548 senior professional titles.
	803 Institute	600 senior engineers and more than 20 provincial and ministerial experts
	802 Institute	850 professional and technical personnel of various types; more than 350 national engineering experts, experts with special government allowances, provincial and ministerial-level academic and technical leaders, and high-tech talents above senior engineers
CASC 5th Academy	All Units	More than 2,100 personnel with senior technical titles, including 8 academicians of the Chinese Academy of Sciences and the Chinese Academy of Engineering, 12 academicians of the International Academy of Astronautics, and 9 academicians of the Russian Academy of Astronautics, 11 national-level experts with outstanding contributions and more than 4,100 senior professional and technical personnel

Sources: (Bayuan Dong Ge八院懂哥 [Eighth Academy, Understanding Brother] 2022o, 2022f, 2022g, 2022h, 2022j, 2022k, 2022l, 2022m, 2022c, 2022d, 2022e, 2022i, 2022n, 2022q, 2022p, 2022a, 2022s, 2022r, 2022b)

Appendix C.
Bibliometric Results of Publications Not Categorized as "Astronomy or Astrophysics"

As a reminder, STPI excluded "astronomy or astrophysics" publications because they frequently contain numerous coauthors given that large, expensive equipment is often used to perform astronomy or astrophysics-related research, which could have biased our findings. All bibliometric analyses were repeated and full results are provided here.

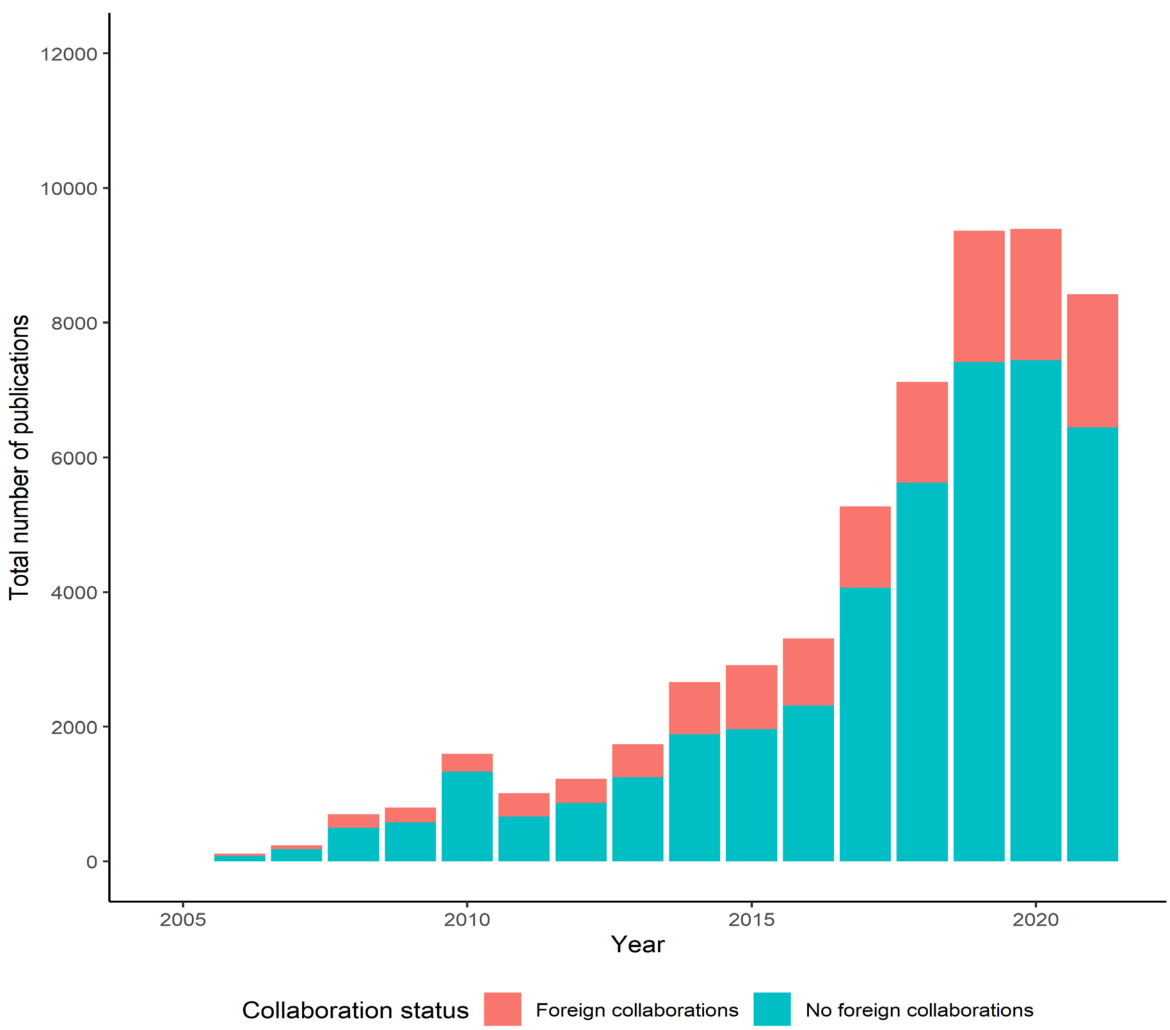

Figure C-1. Number of Non- "Astronomy or Astrophysics" Publications Over Time by Collaboration Status

Table C-1. Percent of Non- "Astronomy or Astrophysics" Publications by Foreign Collaboration Status

Foreign Collaboration Status	Percent of Publications
Has at least one foreign collaborator	23.8%
No foreign collaborations	76.2%

Table C-2. Average (± SE) Number of Citations Received per Publication per Year by Foreign Collaboration Status for Non- "Astronomy or Astrophysics" Publications

Foreign Collaboration Status	Average (± SE) Number of Citations per Publication per Year
No foreign collaborations	1.6 (± 0.02)
Has at least one foreign collaborator	3.5 (± 0.06)

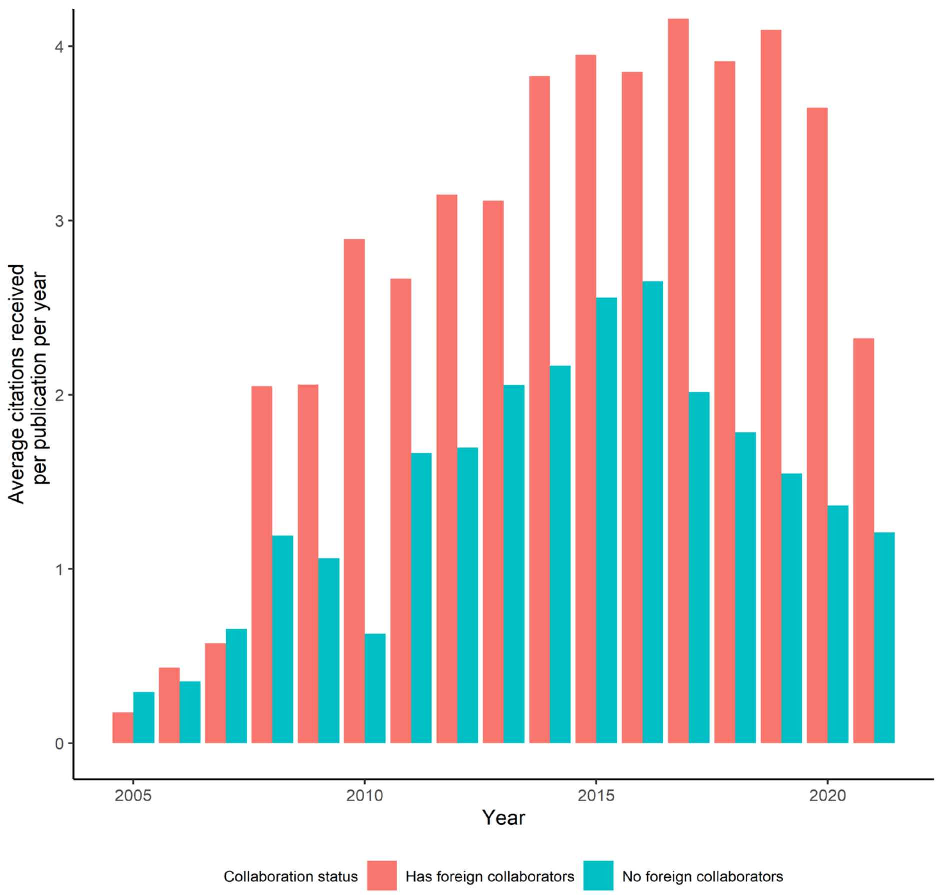

Figure C-2. Average Number of Citations Received per Publication per Year by Foreign Collaboration Status through Time for Non- "Astronomy or Astrophysics" Publications

Table C-3. Top Foreign Collaborators, by Number and Percentage of Total Publications, for Non- "Astronomy or Astrophysics" Publications

Country	Number of Publications	Percent
United States of America	5,720	9.7%
Canada	1,534	2.6%
United Kingdom	1,419	2.4%
Australia	1,053	1.8%
Germany	862	1.5%
France	768	1.3%
Japan	740	1.3%
Italy	567	0.961%
Netherlands	470	0.796%
Spain	341	0.578%

Table C-4. Top 20 Chinese Research Institutions by Total Number and Percentage of Publications That Had at Least One Author with That Affiliation for Non- "Astronomy Or Astrophysics" Publications

Institution	Total Number of Publications	Percent
Chinese Academy of Sciences	7,611	12.9%
Wuhan University	3,123	5.3%
University of the Chinese Academy of Sciences	2,834	4.8%
Beihang University	2,568	4.4%
Tsinghua University	2,030	3.4%
Harbin Institute of Technology	1,968	3.3%
National University of Defense Technology	1,884	3.2%
Northwestern Polytechnical University	1,859	3.2%
Xidian University	1,659	2.8%
Nanjing University of Aeronautics and Astronautics	1,600	2.7%
Beijing Normal University	1,368	2.3%
Beijing Institute of Technology	1,236	2.1%
Shanghai Jiaotong University	989	1.7%
University of Electronic Science and Technology of China	915	1.6%
Zhejiang University	892	1.5%
Peking University	840	1.4%
China University of Geosciences	818	1.4%
Nanjing University	748	1.3%

Institution	Total Number of Publications	Percent
Xi'An Jiao Tong University	738	1.3%
Tongji University	694	1.2%

Table C-5. Top 20 Chinese Research Institutions as Measured by Average Number of Citations Received per Publication per Year for Non- "Astronomy or Astrophysics" Publications

Institution	Average Number (± SE) of Citations per Publication per Year
Wuhan University	4.4 (± 0.16)
Nanjing University	3.6 (± 0.31)
Beijing Normal University	3.6 (± 0.14)
Peking University	3.3 (± 0.21)
China University of Geosciences	3.1 (± 0.18)
Northwestern Polytechnical University	3.1 (± 0.19)
University of the Chinese Academy of Sciences	3.1 (± 0.16)
Xidian University	3 (± 0.11)
Chinese Academy of Sciences	3 (± 0.07)
University of Electronic Science and Technology of China	2.6 (± 0.14)
Harbin Institute Technology	2.5 (± 0.17)
National University of Defense Technology	2.5 (± 0.09)
Tsinghua University	2.4 (± 0.11)
Zhejiang University	2.2 (± 0.12)
Beihang University	2.2 (± 0.08)
Beijing Institute Technology	2 (± 0.1)
Nanjing University of Aeronautics & Astronautics	1.6 (± 0.07)
Shandong University	1.6 (± 0.33)
University of Science & Technology of China	1.5 (± 0.14)
Shanghai Jiao Tong University	1.4 (± 0.1)

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Abbreviations

CALT	China Academy of Launch Vehicle Technology
CAS	Chinese Academy of Sciences
CASC	China Aerospace Science & Technology Corporation
CASIC	China Aerospace Science & Industry Corporation
CAST	China Academy of Space Technology
CETC	China Electronics Science & Technology Corporation
China SatNet	China Satellite Networks Limited
GDP	gross domestic product
IDA	Institute for Defense Analyses
ILRS	International Lunar Research Station
IoT	Internet of Things
LEO	low Earth orbit
NUAA	Nanjing University of Aerospace and Astronautics
PNT	position, navigation, and timing
R&D	research and development
SAST	Shanghai Academy of Spaceflight Technology
SEDC	Space Engineering Development Company
SOEs	state-owned enterprises
STEM	science, technology, engineering, and math
STPI	Science and Technology Policy Institute
VSATs	very-small aperture antennas

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14. ABSTRACT

China's space capabilities have increased rapidly over the past two decades such that it now has one of the most active space programs in the world. With the second highest space expenditures of all spacefaring nations, China maintains robust programs in remote sensing; position, navigation, and timing; communications; human exploration; lunar capabilities; and more. These advancements in space have relied on Chinese scientists and engineers to conduct research and develop the technology needed to be an independent spacefaring nation with a successful space program—rather than relying on partner nations. This study sets out to examine the development and utilization of China's space talent. We employed multi-method approaches including a literature review, analyses of Chinese aerospace higher education institutions, workforce report data, and publication data.

15. SUBJECT TERMS

China; Space; talent pipeline

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